NUMERICAL MODELING TO INVESTIGATE SAFE YIELD IN MAE SAI MULTILAYERED AQUIFERS

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INTRODUCTION

Chiangrai is a northernmost province of Thailand and situated at the golden triangle delta. Chiangrai province is nowadays planned to serve as the regional trade hub among the Yunan Province of the People' s Republic of China (PRC), Myanmar, Loas P.D.R and Thailand through the quadrangle economic cooperation policy. Hence the economy tendency of Chiangrai would expand up due to this mentioned policy. As these matters of facts, Chiangrai will be needed to develop more infrastructures for serving the economic growth in the future and one of crucial infrastructures is water resource. Groundwater is an abundant water resource in Chiangrai and potentially able to be extracted for support this economic growth in the future. Nowadays, there is no any intensive groundwater investigation in Chiangrai to scientifically confirm the existing groundwater resource and assess the groundwater yields for this aquifer basin through a groundwater modeling. Thus Department of Groundwater Resources (DGR) which is the major-role department for manage groundwater resources in Thailand has intensively investigated the hydrogeology of groundwater resources of the aquifers in Chiangrai province and developed groundwater models to assess for these relevant groundwater yields in order to use these data to sustainably manage for the groundwater resources in Chiangrai. The safe yield is an investigated yield for the study. The paper unveils the safe yield in Mae Sai aquifer basin which is a basin in Chiangrai is computed through a 3-D fully groundwater model of Mae Sai multilayered aquifers.

STUDY AREA AND MODEL ESTABLISHMENT

Study Area

Mae Sai Basin situates in the Mae Sai-, Chaing San- and Mae Jan district or so called "Amphoe in Thai" which is the northernmost district of Chaingrai in the northern Thailand (Figure 1). It encompasses the area around 670 square kilometers. North of Basin is closed to Burma, while Eastern basin is bordered by Mae Khong river and Lao P.D.R. Several hills present in the westernmost part of the basin. The northern basin is flat area, while the high terrace areas where the natural recharge exists presents in the southeastern and western basin. The basin's altitude varies from +140 to +1450 m. (MSL). The geological investigation of Department of Groundwater Resources (DGR, 2009) discloses that Mae Sai basin comprises of 4 aquifer-layers which are intercalated by 4 thin aquitard-layers (Figure 2). The porous medias present in an aquifer composed of gravel, sand and sandy-clay, whilst the aquitard's materials is comprised of clay. The thickness of 2^{nd}, 4^{th}, 6^{th} and 8^{th} aquifer-layer is 50, 40, 50 and 45 meters, while 1^{st}, 3^{rd}, 5^{th} and 7^{th} aquitard-layer is 2, 4, 2.5 and 4 meters, respectively.

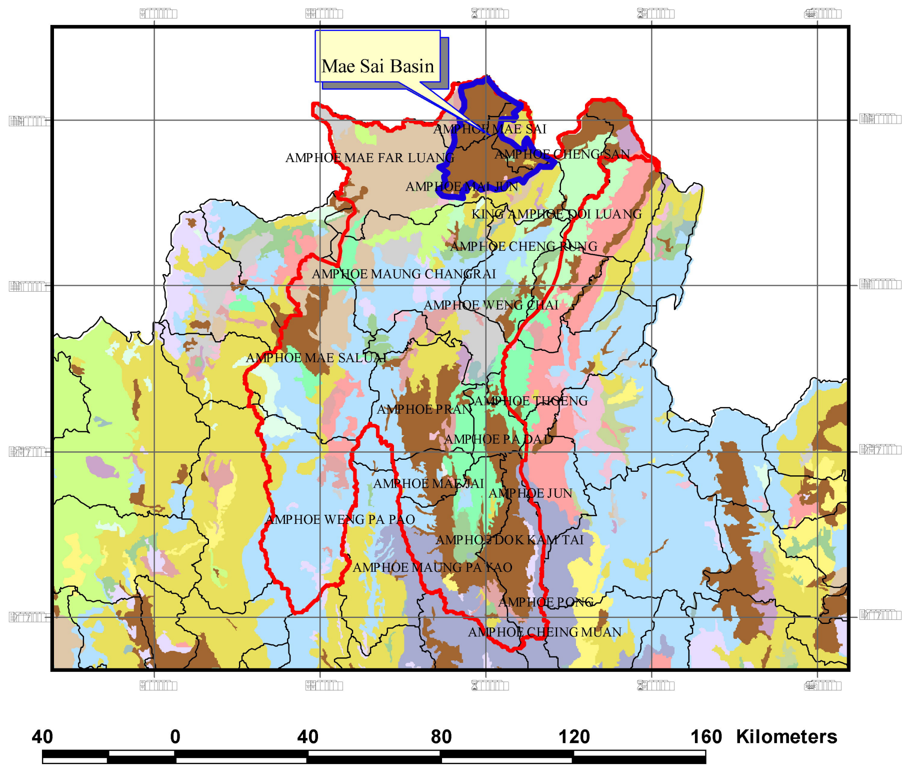

Figure 1 The hydrogeological map of Mae Sai basin

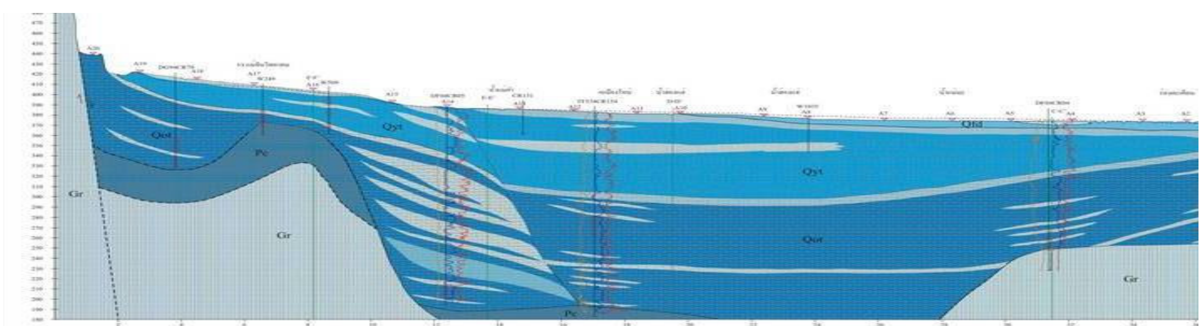

Figure 2 A profile of geological exploration of Mae Sai Multilayered aquifers (DGR, 2009)

Conceptual Model

As ealier mentioned, Mae Sai multilayered aquifers is composed 8 layers, namely, one top clay layer, 4 aquifer layers which are intervened by 3 thin aquitard layers, therefore the conceptual model of Mae Sai is meticulously conceptualized according to the all available geological, hydrological and other conditions (Figure 3). Furthermore, the observed groundwater levels draw the region groundwater flow flows from the eastern, western and southern basin flanks toward the plain in the north. These basin flanks and plain are set up as the recharge area and they are separately zoned concerning on different land uses, rainfalls and evaporations in form of net recharge. The areas of hills and mountains are specified as "No Flow Boundary". The northern basin which is closed to the Union of Myanmar are named as "General Head Boundary". The Nam Mae Kam and Khong river are fixed as " River Boundary".

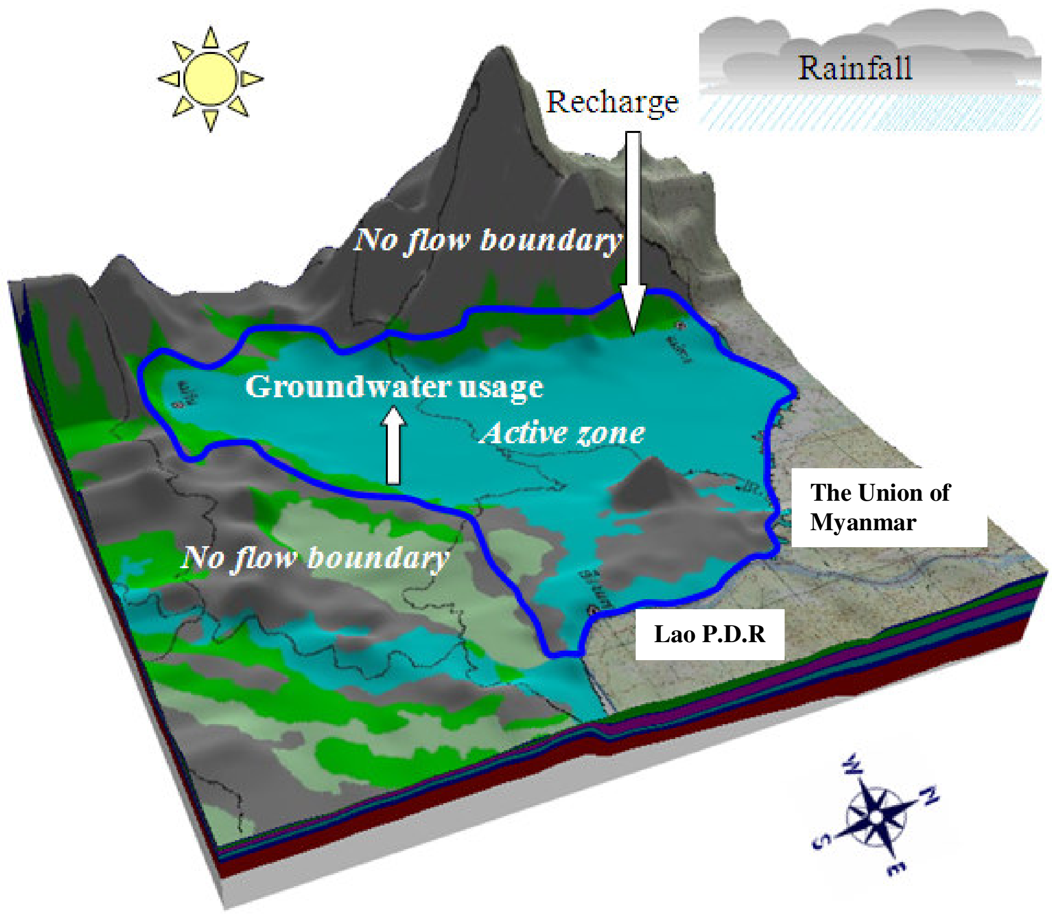

Figure 3 The conceptual model of Mae Sai multilayered aquifers

Model Implementation

The next a fully 3-D of FD of groundwater model which is comprised of top unconfined- and 7 confined aquifer layers is developed to synchronize with the conceptual model. Aftermath, the grid spacing of groundwater model is optimized by several groundwater model runs so that the plot between grid spacing versus error of measure (Figure 4) is able to be drawn. This plot provides the optimal grid spacing of 400x400 square meters for Mae Sai multilayered aquifers which this grid spacing turns out the lowest error of measure with the available data. The fully 3-D of FD of Mae Sai groundwater model are presented in Figure 5 is horizontally discretized as 400x400 square kilometers, while vertically discretized according to the vertical geological units from the geological investigation (DGR, 2009).

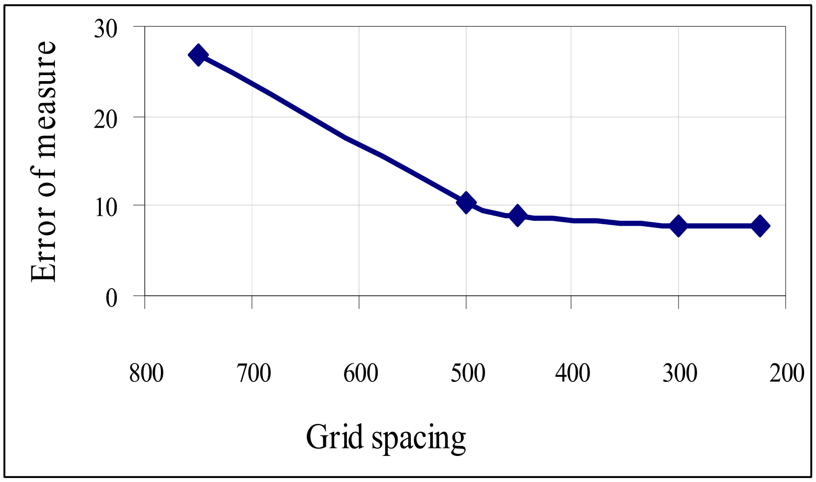

Figure 4 Grid spacing versus error of measure of Mae Sai groundwater model

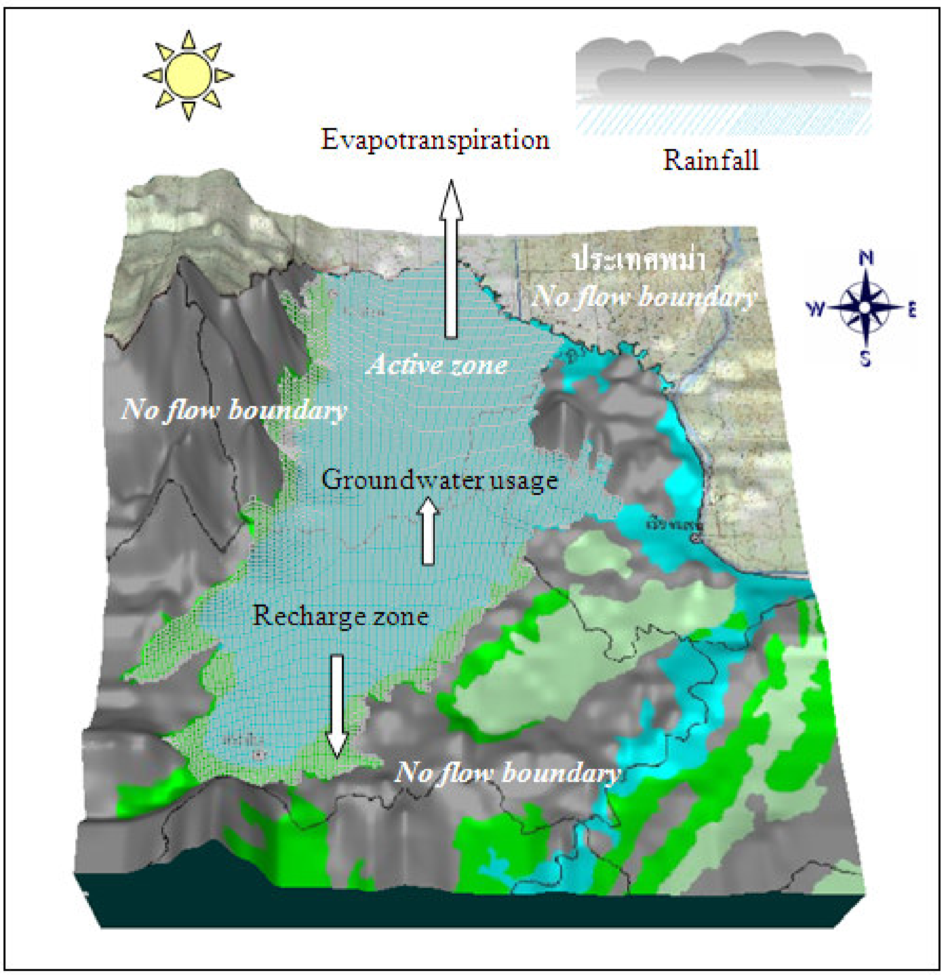

Figure 5 The fully 3-D of FD of Mae Sai groundwater model

GROUNDWATER MODEL CALIBRATION

The groundwater model calibration is induced thereafter developing groundwater model in order to verify the model can reasonably mimic the groundwater system. Since the groundwater level has been not yet measured in the study area before, the Department of Groundwater Resources then develops the monitoring wells and measure the Piezometric head as long as possible (Figure 6). The Piezometric head are measured from January to June, 2009. The steady state – and transient calibration are done with these measured water tables and Piezometric heads.

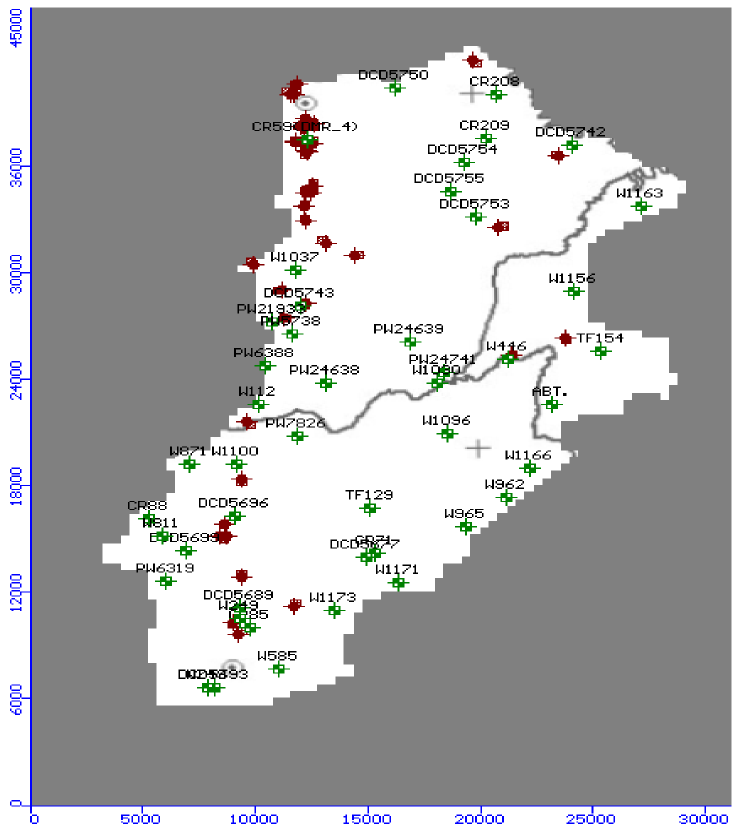

Figure 6 Monitoring wells in the Mae Sai aquifers basin

The steady state calibration is conducted to calibrate the set of hydraulic conductivity and recharge. The evaluation of error measures are assessed in both quantitative and qualitative aspects (Anderson and Woessner, 2002). The quantitative assessment is shown in the scattered plot between observed head versus calculated head (Figure 7). The scattered plot shows that the parameters are well-calibrated, as all correlated points are laid within the band of 95% confident limit. In the other hand, the qualitative assessment is evaluated by spatial plot between observed- and calculated head (Figure 8), it discloses that the regional flow of observed- and calculated head reasonably conform to each other. This means the set of calibrated parameters are well-calibrated in the quantitative view point.

The transient calibration aims to calibrate the storage and recharge parameter. The quantitative assessment is induced to evaluate the calibration result by comparing between observed- and calculated Piezometric head (Figure 9). The result shows is reasonably calibrated, as it expresses an acceptable conforming between these data

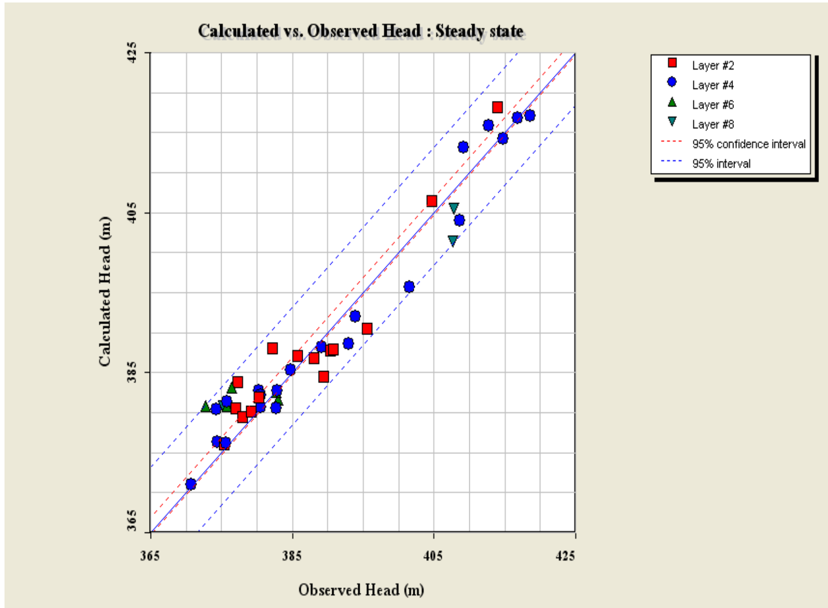

Figure 7 Scattered plot of observed head versus calculated head in steady state calibration

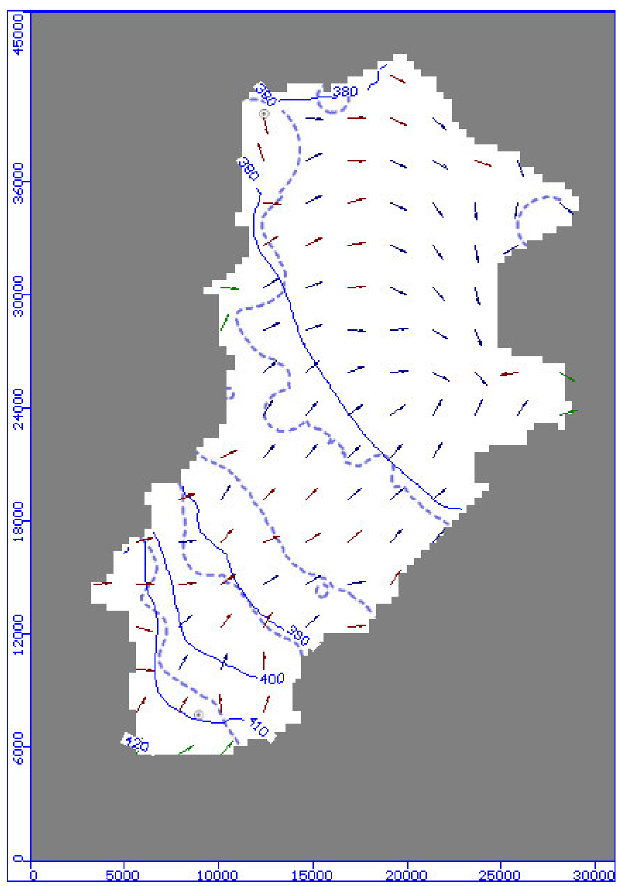

Figure 8 An example of spatial distribution of observed- and calculated Piezometric head in layer 2

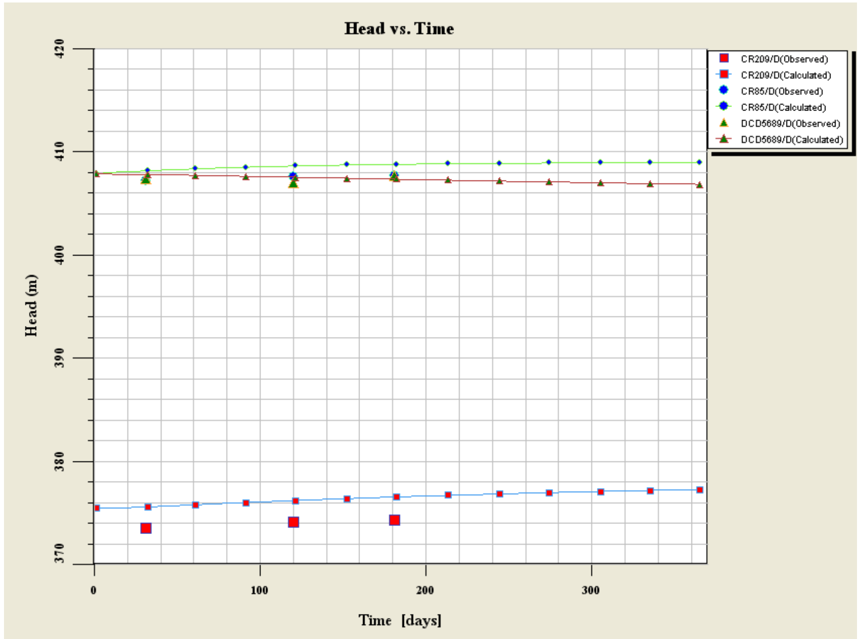

Figure 9 Transient plot between observed- and calculated Piezometric head

SAFE YIELD

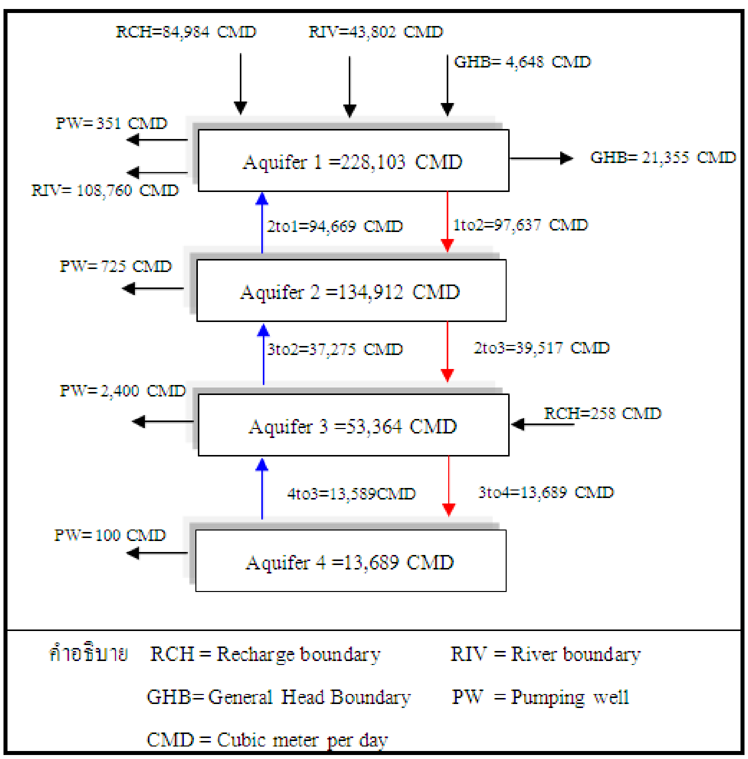

Figure 10 Volumetric budget of Mae Sai aquifers basin in the steady state

Safe yield has been defined in various definitions (Bouwer, 1978; Todd, 1980 and Massachusetts Department of Environmental Protection, 2008). However, the groundwater uses in Mae Sai basin does not yet face the undesirable hydraulic situation, therefore safe yield in this study is defined as "annual recharge into the aquifers system". The water balance is extracted layer-wise from the volumetric budget of groundwater model (Figure 10). The safe yield under the above definition is about 85,000 CMD which is contributed from the net recharge. Therefore the safe yield for Mae Sai aquifers basin is 85,000 CMD.

RESULTS AND DISCUSSION

From the volumetric budget, the recharge mainly exists in the first layer. The sinks are from the river leakage and net recharge in the first aquifer layer, while main withdrawal exists in the layer 3rd, 2nd, 1st and 4th layer, respectively. The first aquifer stores the greatest amount of groundwater, but it is closest to the surface and overlaid by thin clay layer, therefore it is highly sensitive to be contaminated from the surface and some existing minerals in the porous media of first aquifer itself. These induce the groundwater may be poor quality for utilization and consumption in some area.

CONCLUSIONS

Mae Sai multilayered aquifers is in the Chiangrai province where is projected to be a trade hub in the region. The groundwater resource may be a water source to serve its economical growth and then is assessed in a form of safe yield through the fully 3-D of FD of groundwater model. The conceptual model of Mae Sai multilayered aquifers is conceptualized according the geological and hydrological investigation. Aftermath the 3-D groundwater model is set up and calibrated. The calibration shows the set of parameters are well-calibrated. The safe yield is calculated and turns out 85,000 CMD for Mae Sai multilayered aquifers.

ACKNOWLEDGMENT

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