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Effects of River Water on Groundwater in Cambodia

by

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Abstract

The seasonal fluctuation of surface water especially in the wide rivers significantly contributes to the changes of groundwater in the aquifer system. This consequent affects the solute transport and biochemical processes in the system. Therefore, the water interaction is a key to build up the reactive solute transport model in the future study. In order to achieve the above objective, a two dimensional groundwater flow model coupled with a groundwater recharge model was applied in central and southern parts of Cambodia.

The variation of river water elevations were taken into account in the modeling processes. The model results confirmed the river and groundwater interaction that the Tonle Sap River always gains the supply from groundwater at the northwestern mountainous region and groundwater elevations raised higher than river in Bassac and Mekong River in dry season and vice versa in rainy season.

Keywords: Groundwater flow model, Mekong River, Tonle Sap River, Bassac River, Surface and groundwater interaction

1. Introduction

The study area locates at the central and southern parts of Cambodia with 157 km in width and 167 km in length and includes three major rivers: Mekong, Tonle Sap, and Bassac rivers. The Mekong River is the largest river in the Southeast Asia and full of water, forest, and aquatic resources. It starts from the southeastern Himalayan Mountains and empties out into the South China Sea with 4200 km in length. It ranks tenth in terms of discharge[1)]. The study region of the river considered in this study is the part of the Lower Mekong Basin located in Cambodia (**Fig. 1**). The selected area for this study experiences two distinctive monsoons that are the rainy southwest monsoon and the dry northeast monsoon. The average annual precipitation in this area is about 1680 mm across the basin. The precipitation falls about 85% during the rainy season of southwest monsoon which usually lasts from May to October with the direction from Indian Ocean. The northeast monsoon from China takes place from October to April that marks a dry condition in the

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basin [2)3)]. The basin receives the regular rainfall during the rainy season. Therefore, it leads to the flood in this area from July to December with the average discharge 25,000 m^3/s in Mekong River. From January to June, it is a low flow period and has an average discharge 6,000 m^3/s. Two large tributaries of Mekong River join at Phnom Penh, the capital city of Cambodia. The Tonle Sap River flows from Mekong River to the Great Lake (Tonle Sap Lake), and Bassac River flows towards the China Sea. The role of Tonle Sap is as a buffer of the Mekong River system floods and the source of beneficial dry season flows. It has about 120 km in length and a maximum inflow velocity of 1.8 m/s.

Groundwater has been considered as the vital sources of drinking water in Cambodia, especially for un-urban residents in Mekong Delta. However, in 2000, the result of drinking water quality assessment in Cambodia revealed 10 groundwater samples with arsenic concentrations >10 ppb[4)]. The elevated hazardous concentrations of arsenic in shallow aquifers associated with alluvial sediments were reported as well[5)]. Within the aquifer, arsenic levels range from 15 ppb to >1000 ppb, and average about 500 ppb[6)].

The water interaction between river and aquifer is leading to the transportation of nutrient in the aquifer system. The understanding of flow characteristic will be beneficial for the future research on geochemical and biological processes. The main objectives of this study are to focus on the interaction of groundwater and surface water and zonation of groundwater and river water flow exchange in central and southern parts of Cambodia.

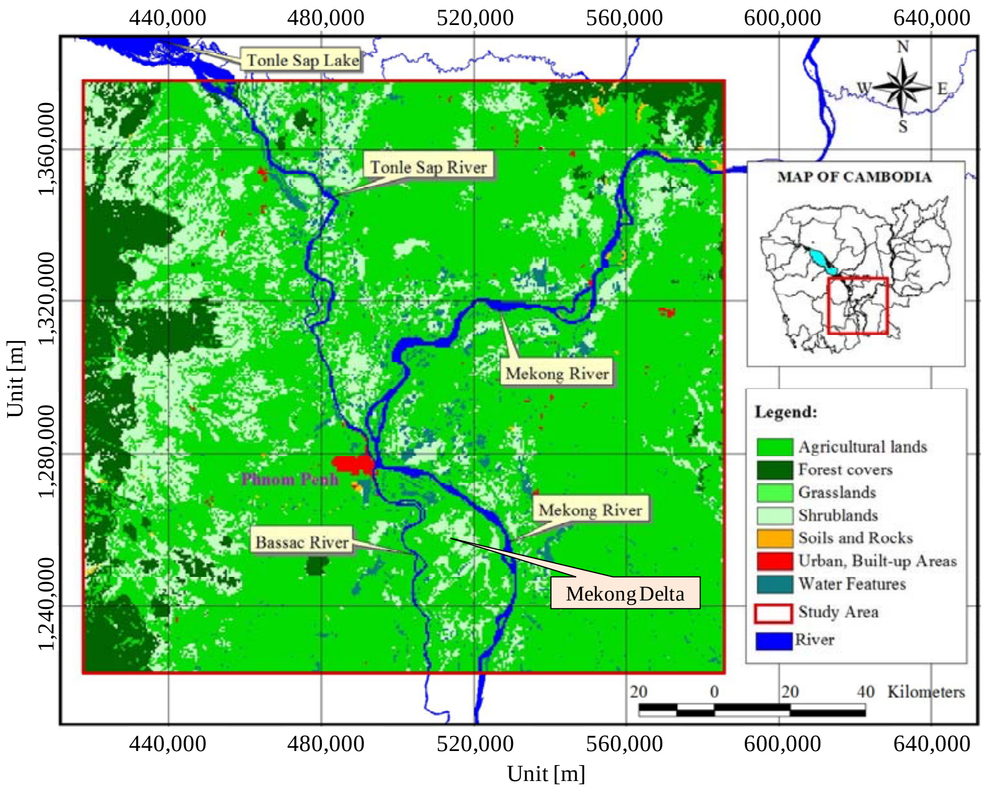


Fig. 1 Location of study area with Universal Transverse Mediator (UTM) Coordinate System (from Ministry of Civil and Urban Planning of Cambodia).

2. Geology

The lithology of rocks in study area was represented by the sedimentary unit, metamorphic unit, and igneous unit[7)8)]. **Figure 2** shows the geological features of study area. The following is the description of every geological unit. The sedimentary unit is dominant, especially the distribution of pediments at the western side and alluvial plain deposits along Tonle Sap, Bassac, and Mekong Rivers. The peneplain laterite deposits can be found at the northeastern part due to the erosion laterite levees of hilly area. The volcanic deposits existed in this area as well. Similarly, the organic deposits are easily recognized in the swamps area and significantly in between Bassac and Mekong Rivers. Alluvial fans deposit along the valley of the mountains and spread until the floodplains sediments in lowland. Terrace alluvial deposits distribute along small rivers in southern part as well Tonle Sap River. Quartzite can be found in the mountainous region at southwestern site, and the distribution of igneous unit such as granite is dominant in mountainous area of western region.

3. Methodology

3.1 Basic equations

Characterization of regional groundwater flow using different type of models can be found in many researches. The prediction of groundwater flow was made possible through the numerical modeling techniques and computer power[9)10)11)]. A groundwater recharge model using tank model combined with groundwater flow model has been developed by Tsutsumi *et al.* (2004)[12)] in order to estimate the water balance of surface and subsurface in coastal area.

In this study, the finite different method is used to numerically calculate the groundwater flow movement and groundwater recharge fluctuation by solving the governing equation of groundwater flow and equation describing the change of water storage in the tank model. Moreover, the changes of river water level have been taken into consideration.

3.1.1 Groundwater flow equation

The model is based on the two equations: Darcy's law and the equation of conservation of mass. The combination of the two equations results in a partial differential equation for the unsteady groundwater flow[13)].

$$n_e \frac{\partial h}{\partial t} = \frac{\partial}{\partial x}\left(kb \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y}\left(kb \frac{\partial h}{\partial y} \right) + q_w \qquad (1)$$

where n_e is the effective porosity, h [L] is the groundwater level in the aquifer at time t, k [LT^{-1}] is the hydraulic conductivity of the aquifer for horizontal flow, b [L] is the saturated thickness of aquifer at time t: $b = h - z$ where z [L] is the elevation of bedrock, and q_w [LT^{-1}] is net recharge rate calculated at time t by groundwater recharge model.

The finite difference approximation has been utilized in order to solve **Equation 1** by changing to the differential format using central difference approximation in space as follows:

$$h_{i,j}^{t} = \frac{HI_{i,j}^{t} + HJ_{i,j}^{t} + h_{i,j}^{t-1} \times \dfrac{n_e}{\Delta t} + q_w}{TI_{i,j}^{t} + TI_{i-1,j}^{t} + TJ_{i,j}^{t} + TJ_{i-1,j}^{t} + \dfrac{n_e}{\Delta t}} \qquad (2)$$

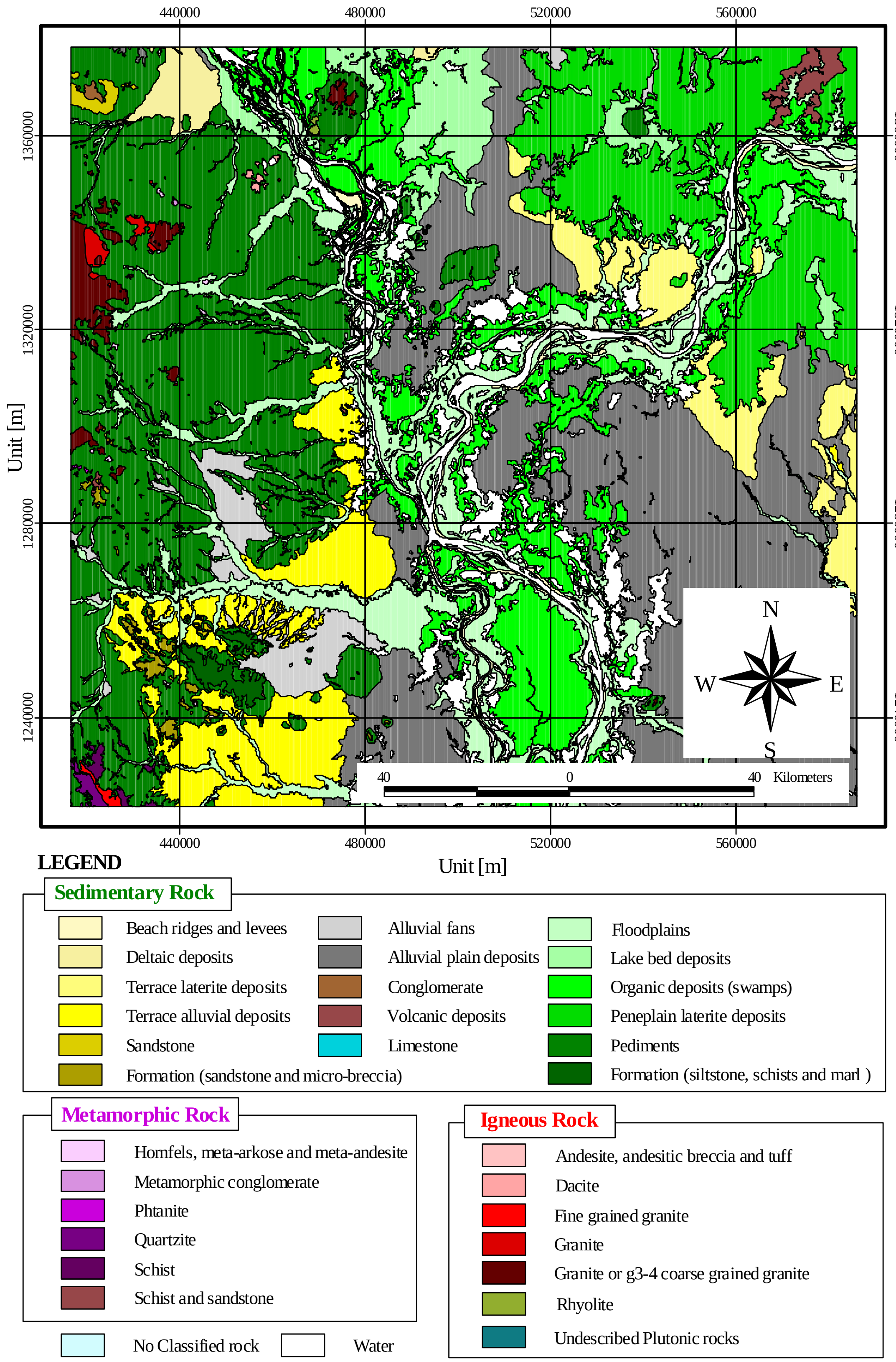


Fig. 2 Geological map of study area with Universal Transverse Mediator (UTM) Coordinate System (from Ministry of Civil and Urban Planning of Cambodia).

where

$$TI_{i,j}^{t} = \frac{2 \times T_{i,j}^{t} \times T_{i-1,j}^{t}}{T_{i,j}^{t} + T_{i-1,j}^{t}} + \frac{1}{\Delta x^2}$$

$$TJ_{i,j}^{t} = \frac{2 \times T_{i,j}^{t} \times T_{i,j-1}^{t}}{T_{i,j}^{t} + T_{i,j-1}^{t}} + \frac{1}{\Delta y^2}$$

$$T_{i,j}^{t} = k_{i,j} \times \left(h_{i,j}^{t-1} - z \right)$$

$$HI_{i,j}^{t} = h_{i-1,j}^{t} \times TI_{i-1,j}^{t} + h_{i+1,j}^{t} \times TI_{i+1,j}^{t}$$

$$HJ_{i,j}^{t} = h_{i,j-1}^{t} \times TI_{i,j-1}^{t} + h_{i,j+1}^{t} \times TI_{i,j+1}^{t}$$

In the study area, the values of hydraulic conductivity (k) are obtained by the pumping tests which were carried out at the 50 boreholes in two-year time by Japan International Cooperation Agency (JICA)[7)8)]. The flood plain at central study area, particularly along the rivers is associated with high permeability reaching the highest value around 5×10^{-2} cm/s.

In contrast, the mountainous area and parts of hilly area consist of low permeability rocks with 4×10^{-6} cm/s. The effective porosity of aquifer was estimated with try-and-error method by fitting the groundwater elevation obtained by numerical simulation at the 40 monitoring wells. After many runs of model, it is revealed that the geological materials in central part have the low effective porosity because of the deposition of sediments in the rivers. At the western region, the low effective porosity rocks can be observed at the valley between the mountains. The rocks at the northern, eastern, and southern parts of study area have highest porosity because most of the products here are from alluvial sediments. In general, the effective porosity distribution values range from 0.09 to 0.28[14)]. The depth of bedrock was determined by JICA in their projects as mentioned above. The resistivity sounding and boreholes drilling methods were implemented in order to define the baserock of aquifer[7)8)]. The bottom of aquifer in floodplain and hilly area is in the form of basin composed of sandstone and shale. The highest elevation of base rock is situated in the mountainous area with the altitude 1,500 m from mean sea level (m.s.l) and the lowest bed rock reaches -308 m of m.s.l.

3.2 River water elevation

The river water level changes are included in the model calculation in order to make the simulation more realistic. The survey data of river water level was collected at the existing stations along the river, and they are interpolated from one station to another in order to calculate the water level in between the stations. The following interpolation is used for the above purpose.

$$h_x = h_2 + \left(h_1 - h_2 \right) \cdot \frac{x}{L} \qquad (3)$$

where h_x is the water elevation at the location between the two stations (upstream and downstream), h_1 is the water elevation at the upstream station, h_2 is the water elevation at the downstream station, x is the distance of the river from downstream station to the calculated location, and L is the distance of the river from upstream and downstream stations.

3.3 Model integration

When all the models are combined together, the groundwater flow, recharge rate, and the changes of river water are solved out at the same time step. These results are utilized as the input for the next time step. Groundwater head is calculated by groundwater flow equation with the consideration of groundwater recharge model. **Figure 3** shows the flow chart of coupled model for the calculation process.

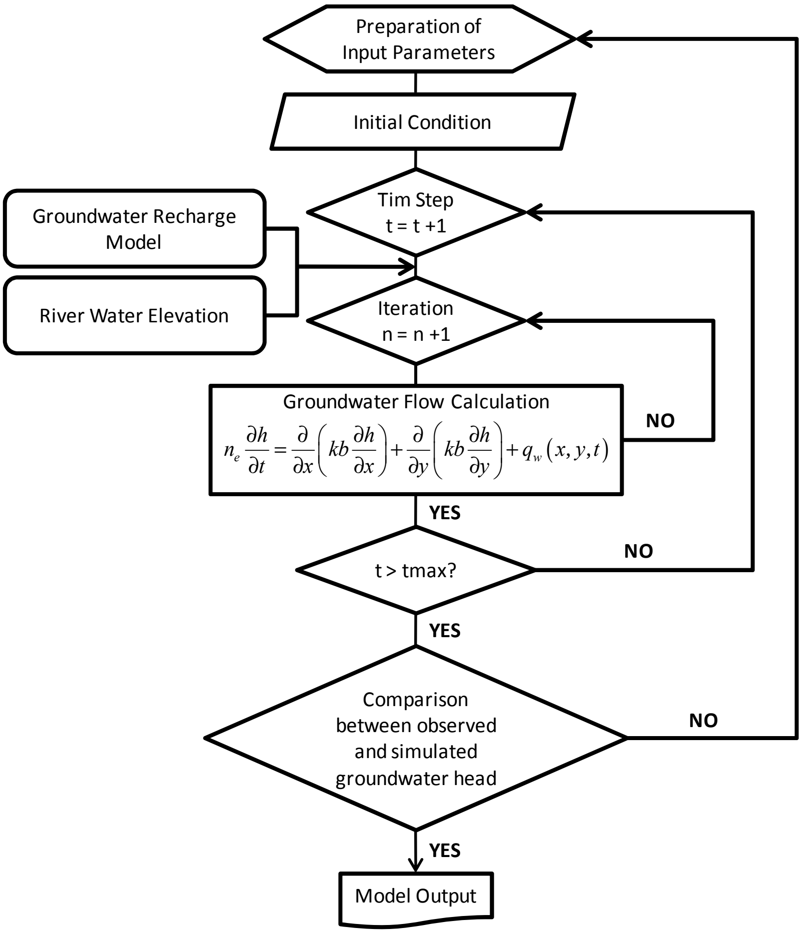


Fig. 3 Flow chart of groundwater flow model coupled with groundwater recharge model and river water elevation changes.

At every time step, the hourly change of river water level and the recharge rate by groundwater recharge model were separately given for the calculation of groundwater head. The parameters such as permeability and effective porosity required for solving the groundwater flow are constant.

Initially, we run the model for four-year period from 1994-1997. The initial condition of groundwater elevation was set equal to the available data in 1997. For the river water level and parameters for recharge model, they were assigned equal to the data record in this period. Then, the model was simulated for four-year period utilizing the temporal data in 1994-1997. The results of groundwater elevation from the simulation were used for the initial condition for the long term simulation from 1994-2006.

The conditions at the boundaries of the aquifer must be properly defined. **Figure 4** shows the simplified conceptual model in the unconfined aquifer of our area. A head-controlled boundary, a boundary with a known potential or hydraulic head, which is time–dependent or –independent[15)], was assigned for the calculation. The rectangular boundary of interest area was considered as head-controlled boundary whose groundwater elevations were assumed to be time-independent. The groundwater table elevations at these boundaries were computed from the interpolation of groundwater elevations at the observation wells. In contrast, the river reaches were treated as the head-controlled boundary whose water elevations were dependent on time. These boundary conditions depend on 8 observation stations at the following locations: Kratie, Kompong Cham, Neak Luong, Phnom Penh Port, Prek Kdam, Kompong Luong, Bassac Chaktomouk, and Koh Khel in **Fig. 5 (a & b)**. During the computation, the groundwater elevation is set equal to the ground surface when the calculated groundwater elevation becomes higher than the ground surface[9)].

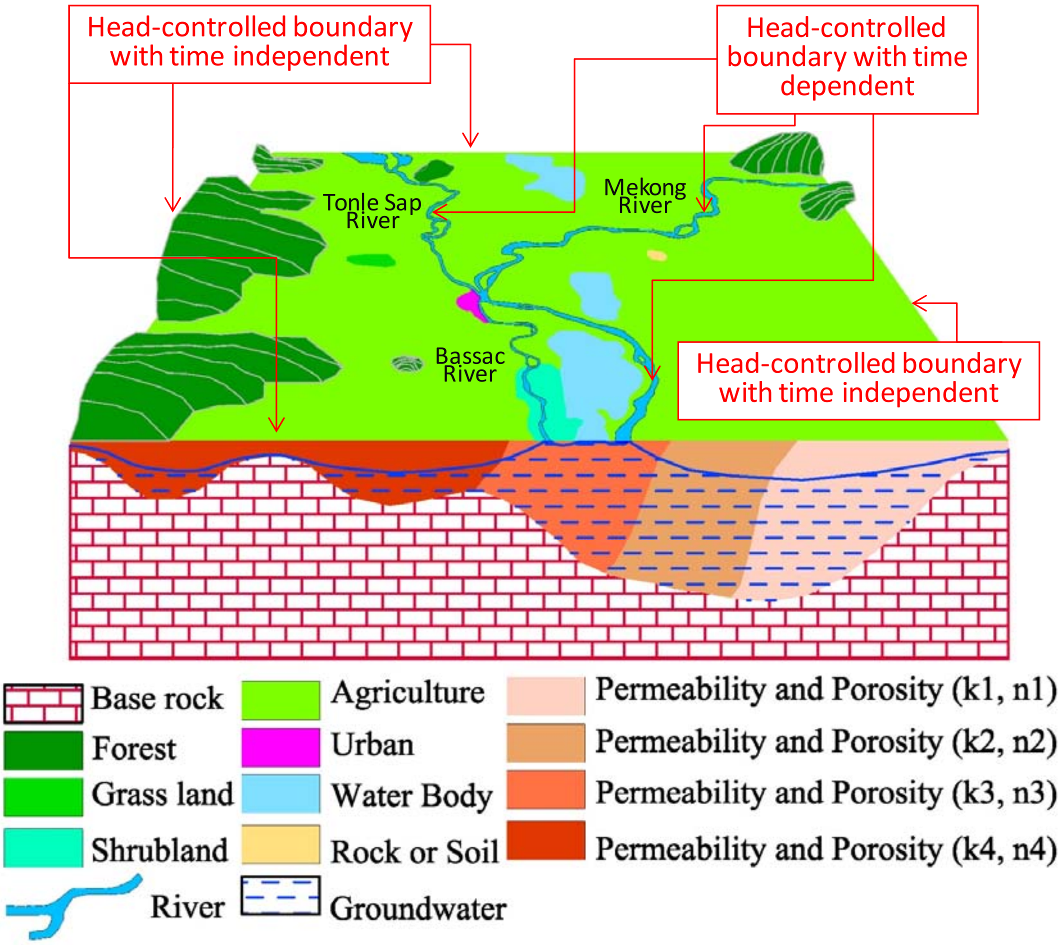


Fig. 4 Conceptual model of study area.

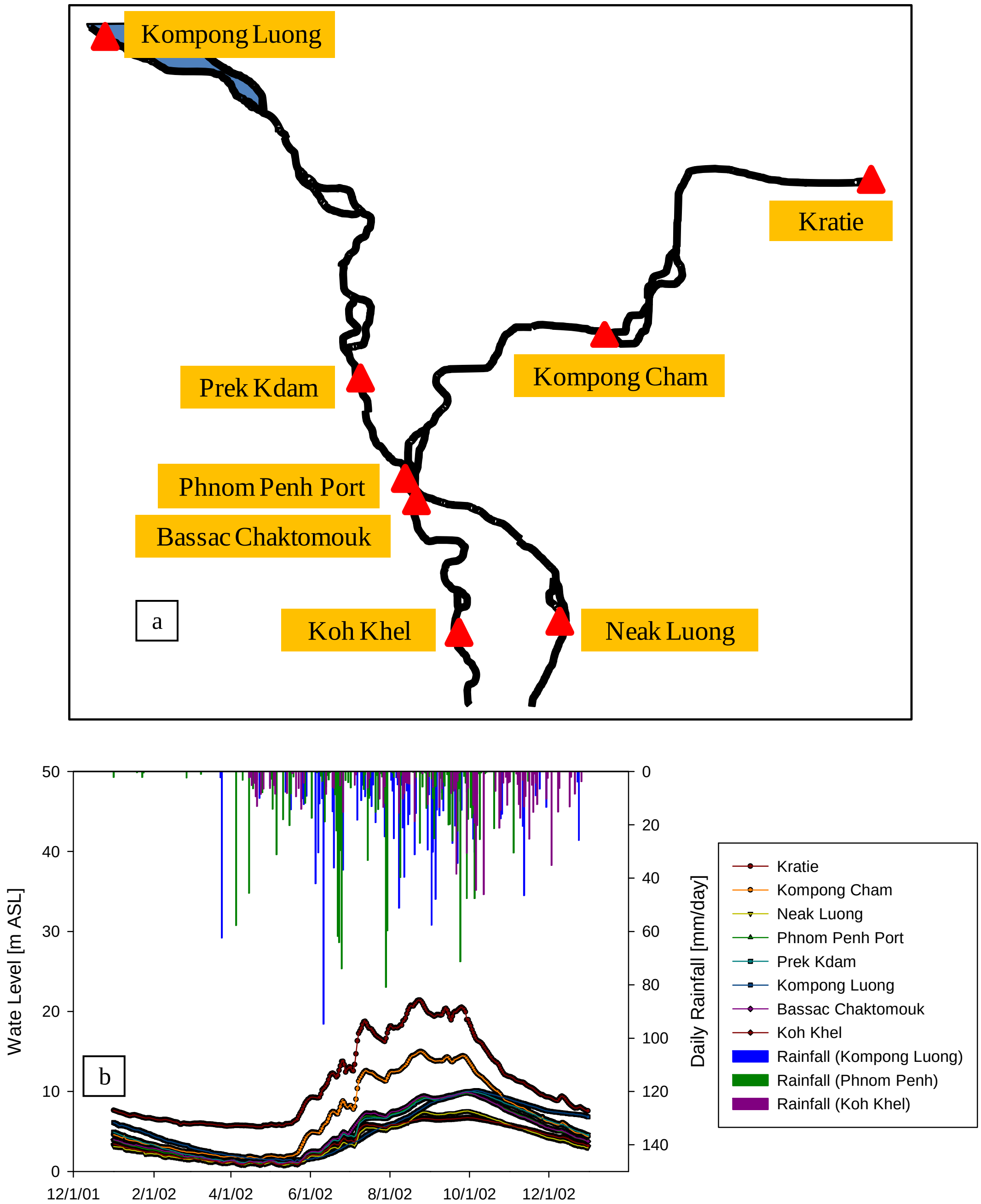


Fig. 5 Hydrological information in the rivers **(a)** sketch of stations in rivers and **(b)** River water elevations verse rainfall in 2002 for head-controlled boundary condition.

3.4 Criteria of evaluation

The Root Mean Squared Error (RMSE) and the Mean Absolute Error (MAE) are used in order to assess the effectiveness of our model and its ability to make precise predictions. The RMSE evaluates the residual between observed and predicted by the model[16)]; the MAE measures the mean absolute error between observed and predicted by the model. The RMSE is calculated by:

$$RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(H_t - \widehat{H}_t\right)^2} \quad (4)$$

and, the MAE is calculated by:

$$MAE = \frac{1}{n}\sum_{t=1}^{n}\left|H_t - \widehat{H}_t\right| \quad (5)$$

where H_t and $\hat{H}_t$ are the observed and predicted groundwater level respectively in [m]; n is the number of observations. RMSE and MAE indicate the deviation between the observed and calculated values.

4. Results and Discussions

The simulation was carried out from 1994-2006 with the increment time step every hour. The model area was discretized into homogenous grid size for both x and y directions. The grid size of 500 m was used in the numerical simulation resulting in 314×334 grids in total. In the following section, the validation of groundwater flow simulation and the effects of the river water level on the groundwater flow will be discussed.

4.1 Model validation

To verify the model results, 40 monitoring wells shown in **Fig. 6** were used. However, they were separated into two parts because the continuous monitoring wells given by JICA had been done in different time (1997 for southern part and 2001 for central part of Cambodia). **Figure 7** shows a comparison between the observed and calculated groundwater levels. It is obvious that the highest and lowest levels are too far different due to the topographical condition of the area. Therefore, three classifications of monitoring wells were considered such as at the mountainous areas (elevations from 113-116 m), hilly areas (elevations from 45-60 m), and lowland areas (elevations from 0-35 m). The simulated results agreed very well among the wells at the lowland and hilly areas. However, the agreement of groundwater levels at the mountainous areas is not sufficient. The high accuracy of lower groundwater levels is due to the sufficient data of monitoring wells, meteorological stations, and river data in the lowland and hilly areas. On the other hand, the input data at the mountainous area was insufficient due to the inaccessible and dense forests resulting in the deviation results.

The RMSE and MAE for model are 0.89 m and 0.57 m respectively. All this suggested that the present coupled model is able to reproduce the groundwater level time series. The RMSE and MAE for model are generally comparable in terms of the regional scale of the study area.

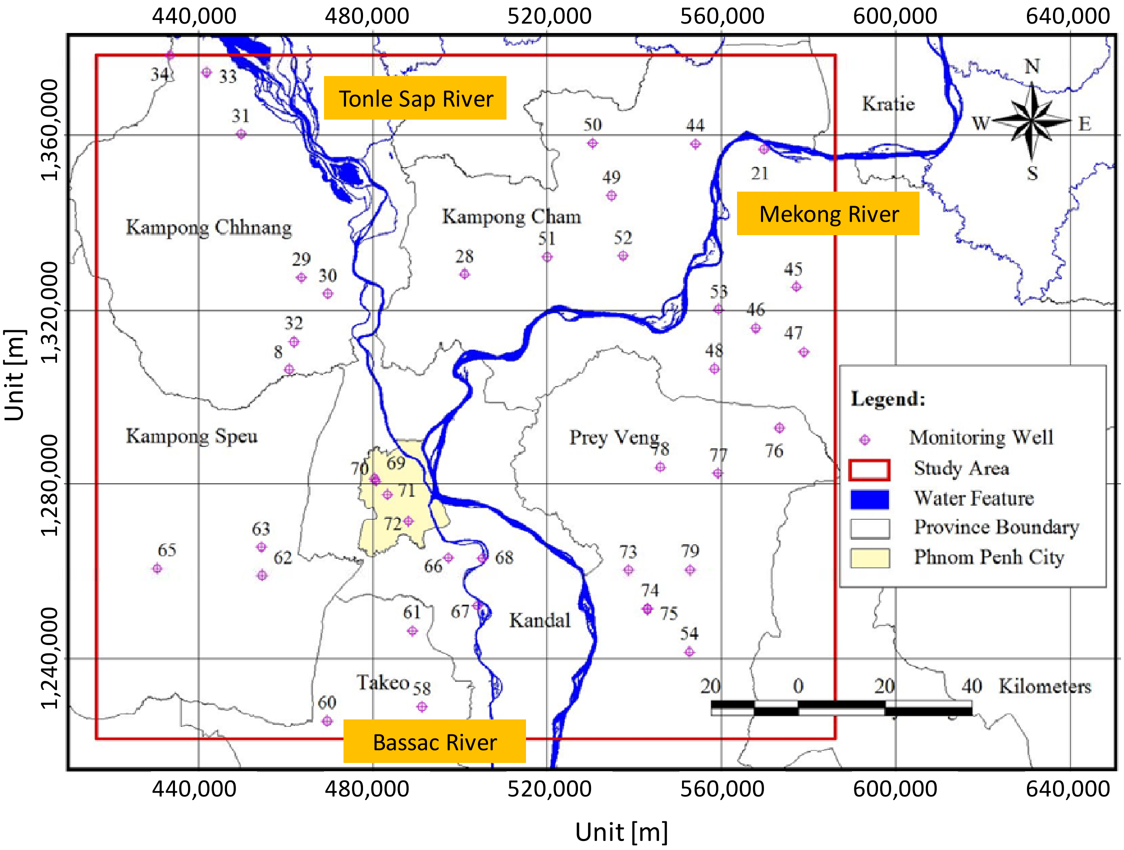


Fig. 6 Monitoring wells for validation of groundwater modeling with Universal Transverse Mediator (UTM) Coordinate System. The number on violet dot represents the name of monitoring well.

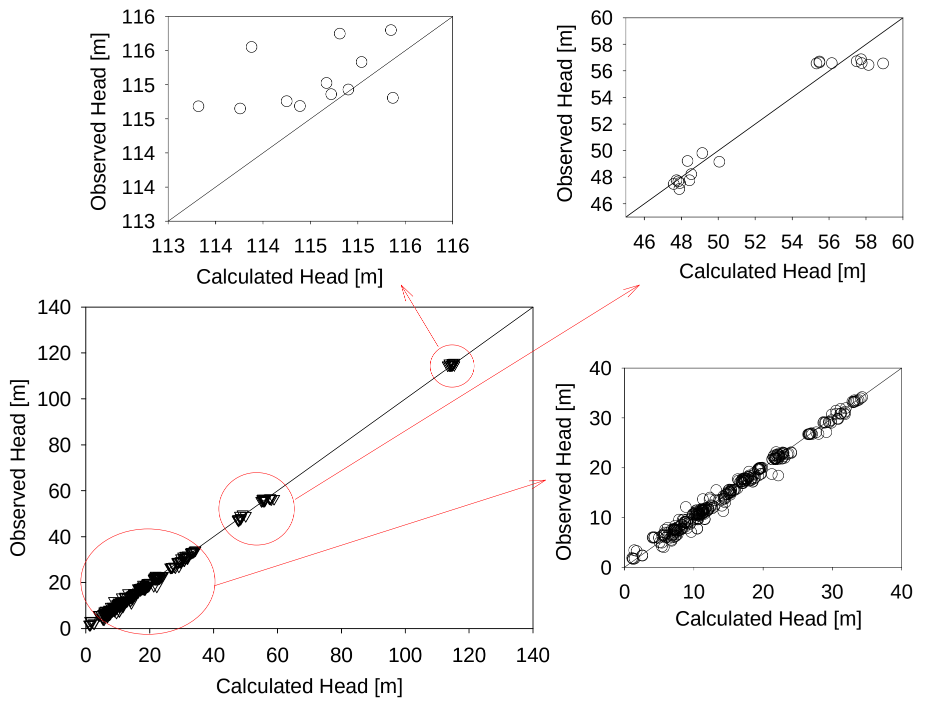


Fig. 7 Comparison of observed and calculated groundwater head.

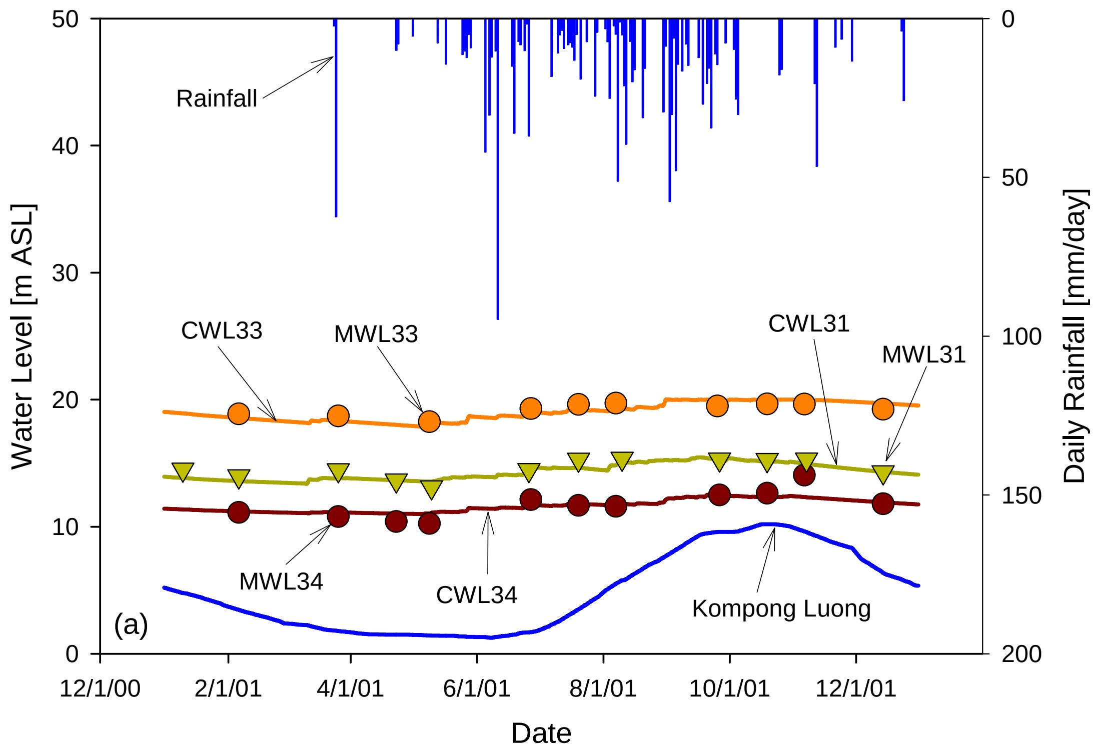
4.2 Groundwater and surface water interaction

In this study, the effects of the rivers on the groundwater system were taken into consideration. The water exchange occurred during dry and wet seasons in the model area. The detail study on the important locations was made by comparing the river water level with simulated groundwater level. The following sections discuss on the hydrographs along Tonle Sap, Bassac and along Mekong Rivers and the changes of groundwater elevations.

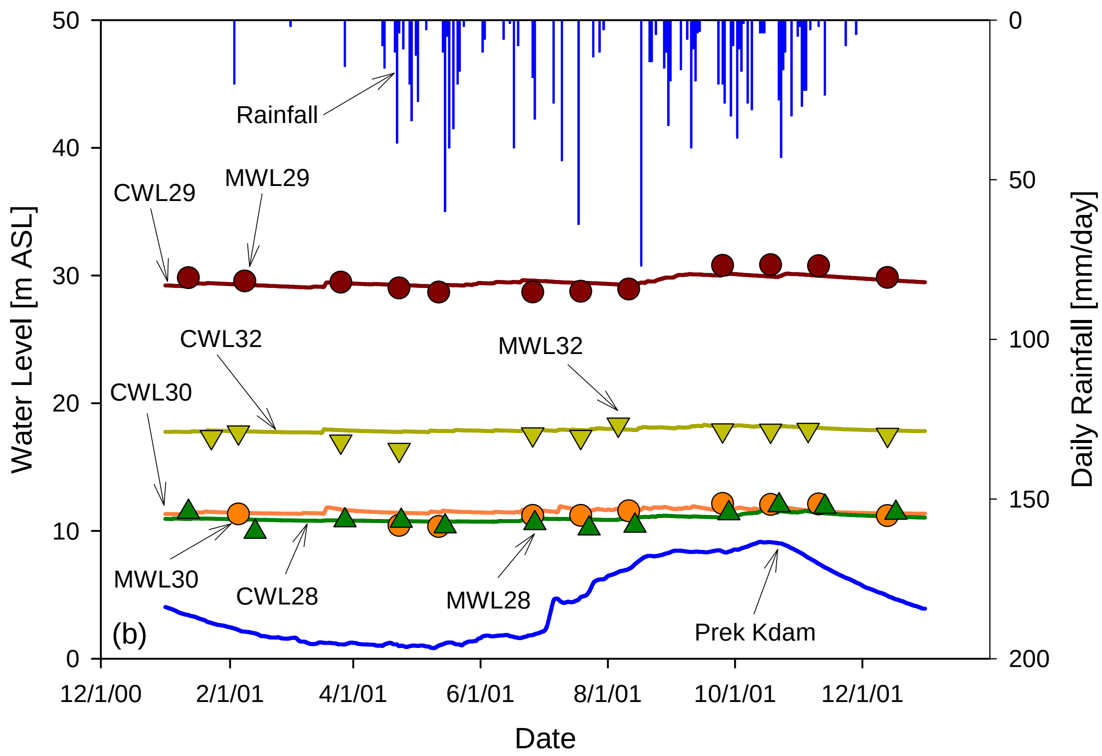
4.2.1 Tonle Sap and Bassac Rivers

Tonle Sap River extends from the North to the middle of model area, while Bassac River continues from the middle to the South of the study area. They play an important role in absorbing the flood during inundation season and maintaining the groundwater during the dry season. From **Fig. 8 (a)** showing the hydrograph of river water and groundwater at the upstream of Tonle Sap River, the influence of the groundwater to the river in rainy and dry seasons can be seen. The comparison of river water level in Tonle Sap River at Kompong Luong station to groundwater levels in wells 31, 33, and 34 located about 5 Km from the river explains how the influences take place. The water supply from groundwater to river always occurs although the river water level is high during rainy season from August to January. Moreover, the hydraulic gradient of groundwater is high at the western part to the river. The same phenomenon also happens at the middle of the river, Prek Kdam station in **Fig. 8 (b)**. The simulation results of wells 28 and 30 show that the groundwater discharges to the river any seasons although the variation of river water level is significantly large between dry and wet seasons. The interaction of groundwater and river water in Bassac River can be observed from **Fig. 8 (c)** which describes the supply of groundwater to the river similar to upstream of Tonle Sap River. On the other hand, the comparison of river water levels in upstream (Bassac Chaktomouk Station) and downstream (Koh Khel Station) of Bassac River with the simulated results of groundwater shown in **Fig. 8 (d)** confirms that the water exchange between groundwater and river water takes place. From this result, the groundwater in Phnom Penh urban area (well 71 and 72) is directly supplied to river water; however, the flow pattern changes gradually from Phnom Penh to downstream. The groundwater fluctuation at well 66, the river water level at Bassac Chaktomouk station is higher than the groundwater level, especially at the end of the rainy season. At wells 67 and 68, the river gains the water from groundwater during dry season and supplies back to the aquifer during the rainy season. The simulation result shows a good correspondence between river water and groundwater fluctuation. In **Fig. 8 (e)**, Bassac River receives the water from the groundwater during dry season and supply back during rainy season; however, there is a delay time of this exchange process. It takes approximately 3 months for groundwater to respond to the river.

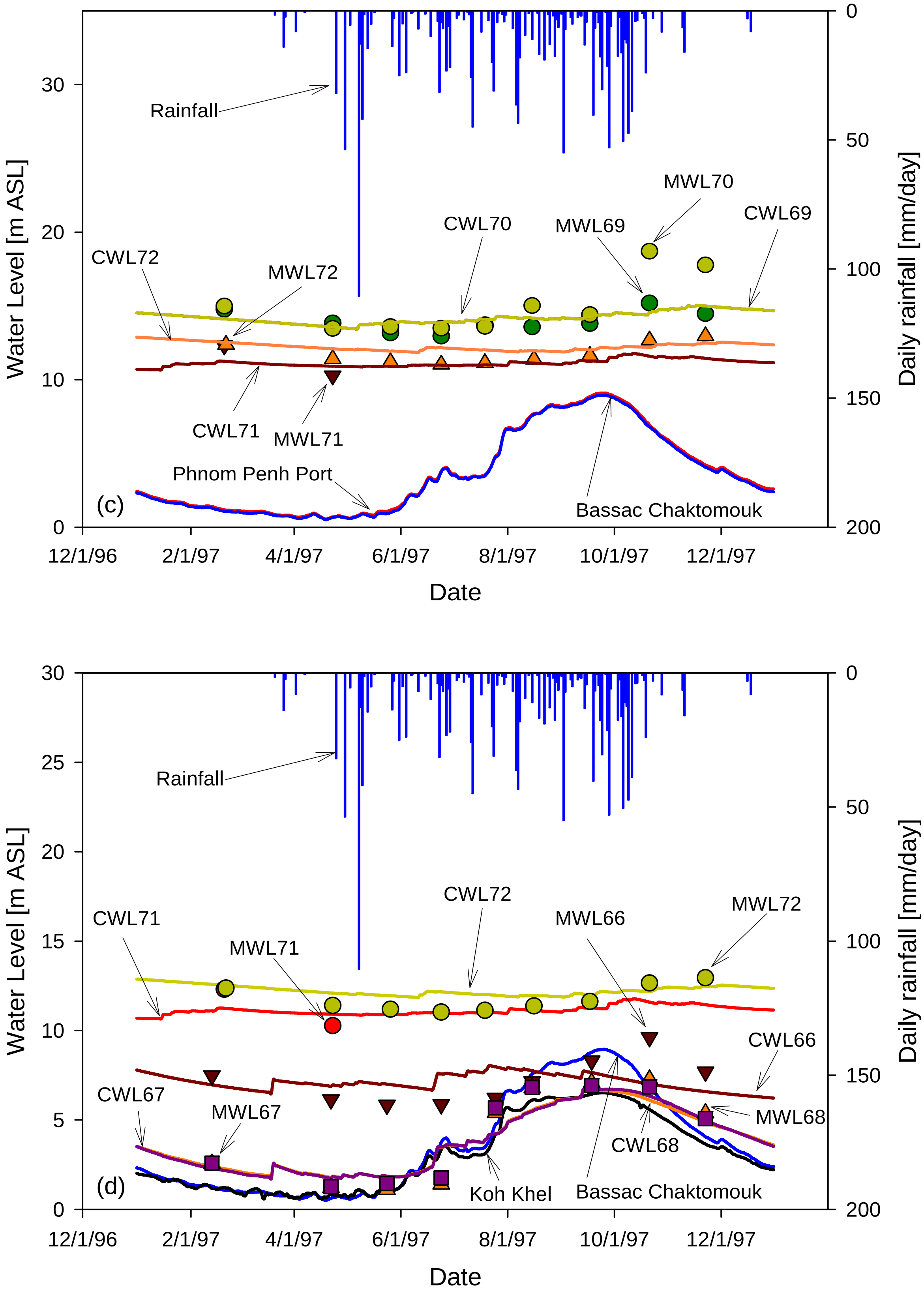
Therefore, the groundwater plays an important role in providing the additional recharge to Tonle Sap River and a part at the upstream of Bassac River (Phnom Penh urban area). The gradual water exchange of groundwater and Bassac River occurs during rainy and dry seasons starting from the suburb of Phnom Penh area to downstream. The delay time of the interaction is significant at the South of the area.



Water Level [m ASL]
Daily Rainfall [mm/day]
Rainfall
CWL33
MWL33
CWL31
MWL31
MWL34
CWL34
Kompong Luong
(a)
Date
12/1/00
2/1/01
4/1/01
6/1/01
8/1/01
10/1/01
12/1/01



Water Level [m ASL]
Daily Rainfall [mm/day]
Rainfall
CWL29
MWL29
CWL32
MWL32
CWL30
MWL30
CWL28
MWL28
Prek Kdam
(b)
Date
12/1/00
2/1/01
4/1/01
6/1/01
8/1/01
10/1/01
12/1/01



Water Level [m ASL]
Daily rainfall [mm/day]
Rainfall
CWL72
MWL72
CWL70
MWL69
MWL70
CWL69
CWL71
MWL71
Phnom Penh Port
Bassac Chaktomouk
(c)
Date
12/1/96
2/1/97
4/1/97
6/1/97
8/1/97
10/1/97
12/1/97
Rainfall
CWL71
MWL71
CWL72
MWL66
MWL72
CWL66
CWL67
MWL67
MWL68
CWL68
Koh Khel
Bassac Chaktomouk
(d)
Date

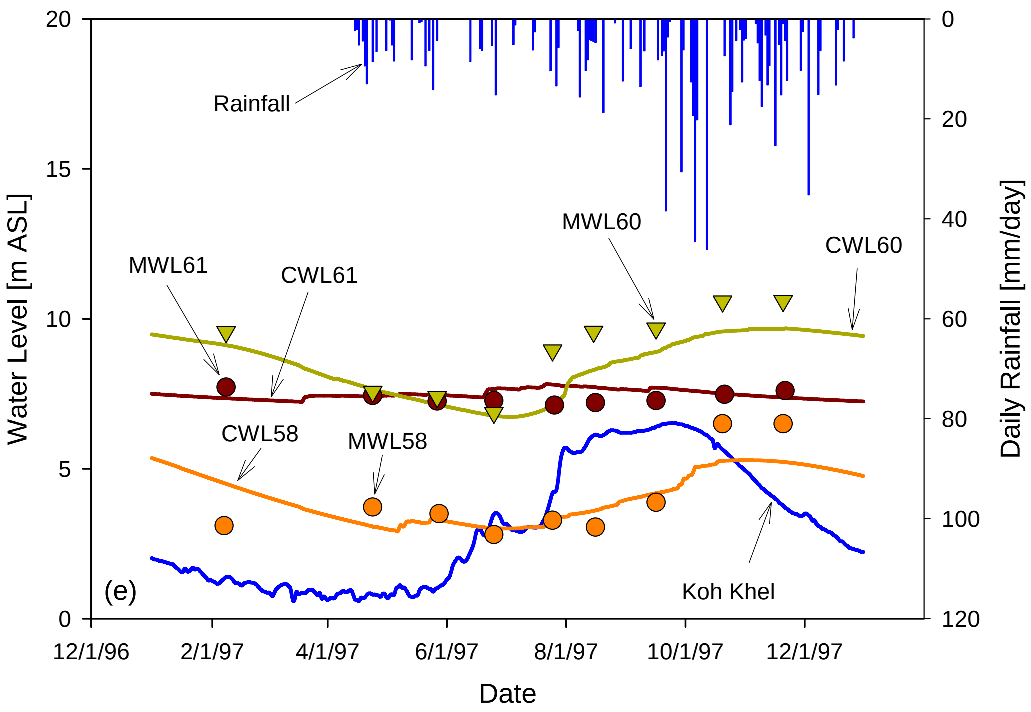


Fig. 8 One-year graphs for selected wells and river water levels showing the interaction between the surface water and groundwater **(a)** river water elevation at Kompong Luong station, upstream of Tonle Sap River, and calculated (CWL) groundwater in 2001 **(b)** river water elevation at Prek Kdam station, middle of Tonle Sap River, and calculated (CWL) groundwater in 2001 **(c)** river water elevations at Bassac Chatomouk and Phnom Penh Port stations, upstream of Bassac River, and calculated (CWL) groundwater in 1997 **(d)** river water elevations at Bassac Chatomouk and Koh Khel stations, upstream and downstream of Bassac River, and calculted (CWL) groundwater in 1997 **(e)** river water elevation at Koh Khel station, downstream of Bassac River, and calculated (CWL) groundwater in 1997.

4.2.2 Mekong River

Mekong River in the model area flows from the northeast to the south of Cambodia. It controls the regime of Tonle Sap and Bassac Rivers as well as the flood at the floodplain area. To identify the interaction between groundwater and river water along Mekong River, the hydrograph of river from two different stations, Kompong Cham (upstream) and Neak Luong (downstream) stations were selected. **Figure 9 (a)** shows the discharge of groundwater to the river in both seasons at the northeastern part of the study area.

The groundwater elevations at all of the monitoring wells are higher than the river water level. The significant changes of water level in the river do not affect so much to the aquifer. In **Fig. 9 (b)** shows the interaction behavior at Neak Luong Station (downstream of Mekong River) where the selected monitoring wells are located at the right side of the river. Well 54 and 73 showed the water exchange between groundwater and river during the late rainy season (August to December). The exchange is similar to what happened in the well 60 of Bassac River downstream near Koh Khel Station. In dry season, groundwater always discharges to the river, according to the hydrograph showing in **Fig. 8 (e)**.

Through this analysis, it is shown that groundwater discharges to the Mekong River at the upper part. The groundwater levels in the monitoring wells are higher than the river water level regardless the significant fluctuation of river water level. At downstream of the river, the river gains the supply from groundwater during the dry season while loses during the rainy season. However, the interaction takes places with the time delay.

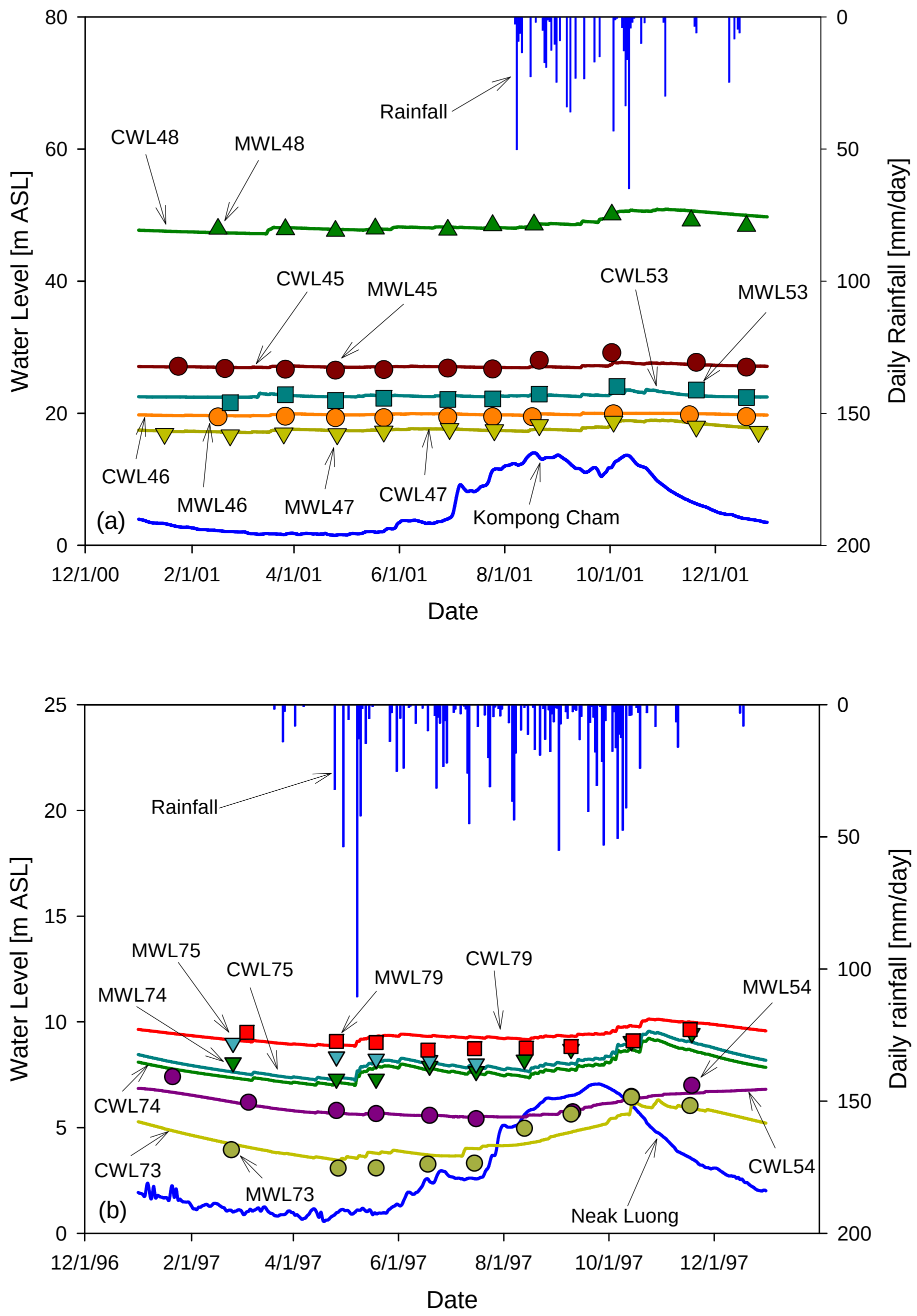


Fig. 9 One-year graphs for selected wells and river water levels showing the changes of surface water and groundwater **(a)** river water level at Kompong Cham station, upstream of Mekong River, and calculated (CWL) in 2001 **(b)** river water level at Neak Luong station, downstream of Mekong River, and calculated (CWL) groundwater in 1997.

4.2.3 Groundwater and river water flow exchange zonation

In this section, the characteristics of groundwater exchange in the study area were categorized based on the output of numerical simulation. The zonation of flow exchange between groundwater and river water helps not only to have a better understanding about the subsurface flow in the vulnerable locations to the pollutants such as arsenic as example but also to specify the study to more detail in the future. Zone division was determined based on the above river and groundwater interaction analysis, groundwater contour map, and groundwater flow velocity. The monthly results of groundwater level from numerical simulation in 2002 were compared in order to determine the location of water exchange location. At the same time, the monthly groundwater flow velocity maps were also utilized to see the changes of velocity component, especially along the places of water exchange (determined by the comparison of groundwater level). Finally, the zone division of groundwater and surface water were drawn, and the wide of this zone was confirmed with the above groundwater interaction analysis in section 4.2.1 and 4.2.2. The grey dot area (**Fig. 10**) along the rivers shows the boundary of river effect on groundwater. Three cross sections are presented in this paper in order to observe the consequences from the flow exchange during dry and wet season. In **Fig. 11**, the extensions of river water elevation during flooding period were made to make them more realistic. However, during the model calculation, the expansion area was not considered due to the small amount of covered grid number as well as the narrowness of river widths comparing to the grid size (500 m).

In **Fig. 11 (1)**, Tonle Sap River gains discharge of groundwater coming from the mountainous and hilly areas at both sides of the river. The cross-sections A-A' shows the monthly groundwater variation along Tonle Sap River. Groundwater levels at the east of Tonle Sap River significantly change every month, while the west side does not fluctuate so much. **Figure 11 (2a & b)** is located along Mekong River. The river gains the recharge of groundwater in the hilly areas at the both sides of river. The cross-section B-B' (**Fig. 11. 2b**) shows the little change of groundwater in this location. On the other hand, the groundwater mostly supplies to the Mekong River, but only three months (August, September, and October) which the water level in the river is higher than groundwater i.e. flooding period. **Figure 11 (3a & b)** is located at the south of the area, along Bassac and Mekong River. Both the aquifer and river supplied the water to each other during the dry and rainy season. The cross-section C-C' (**Fig. 11. 3b**) shows the change of groundwater, river and lake water level. The exchange of groundwater and river during the rainy and dry seasons takes place. Moreover, the lake nearby the river receives the water from the river. It also influences the groundwater at the surrounded areas.

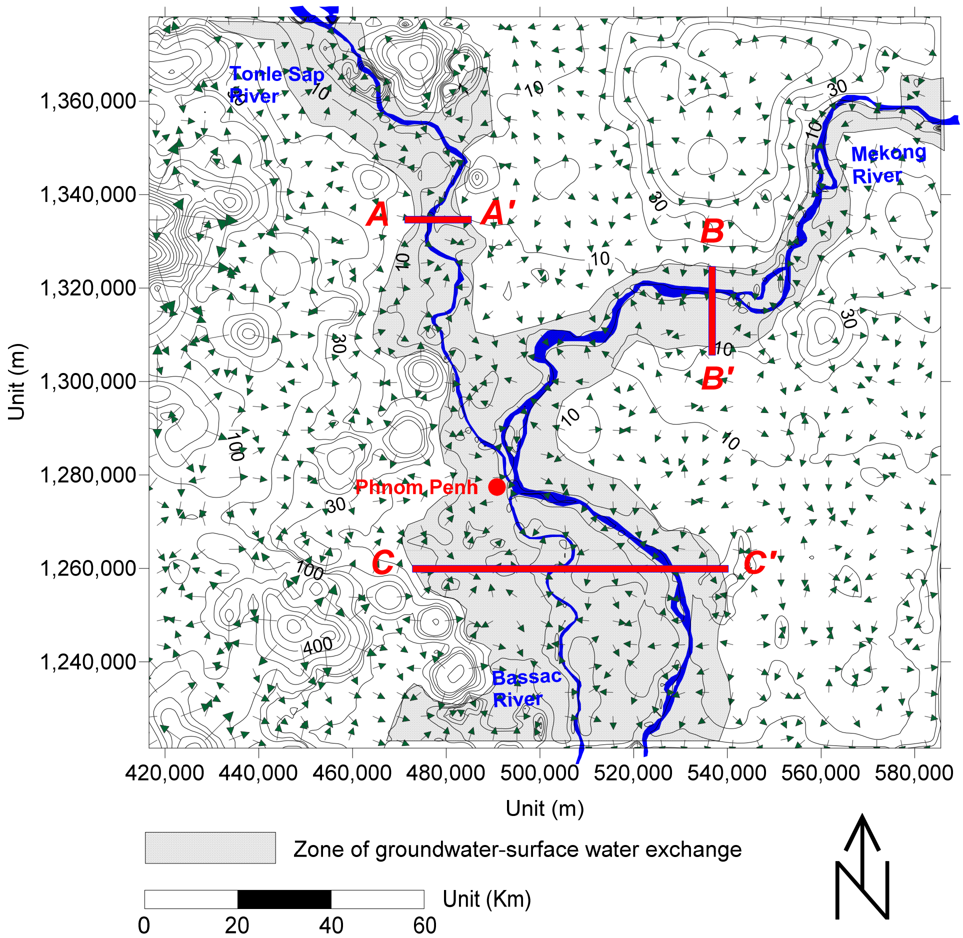
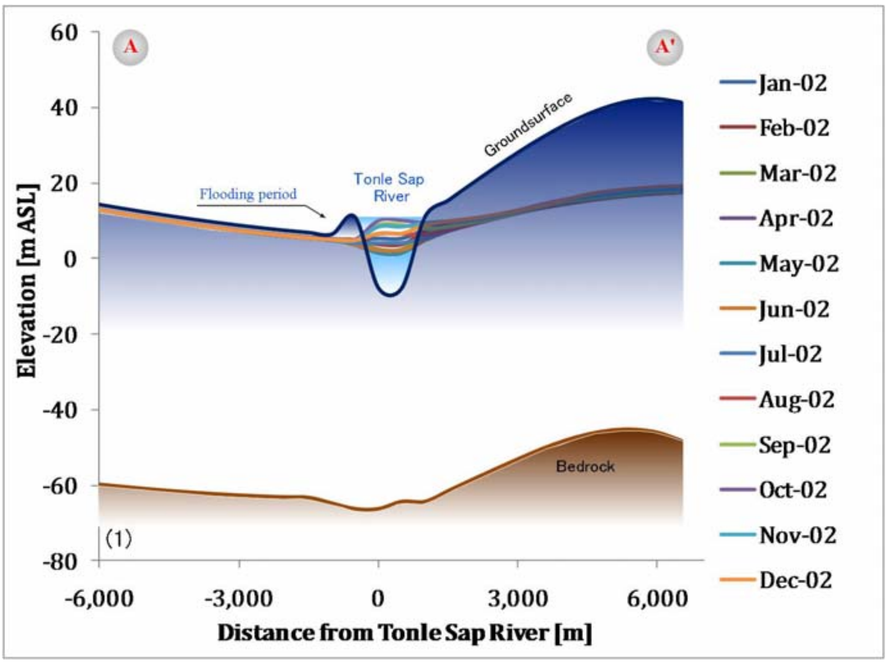
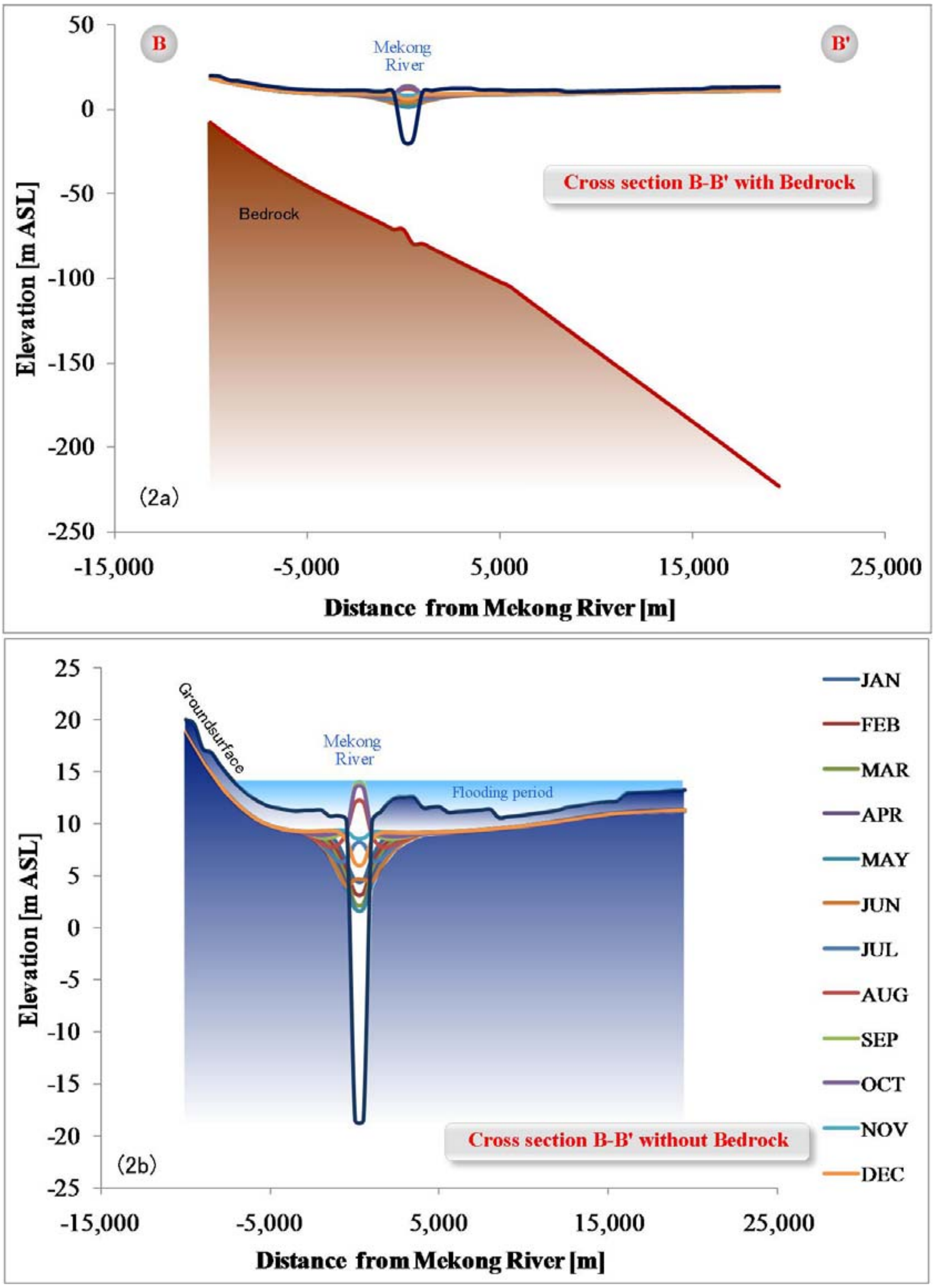


Fig. 10 The zonation of groundwater—river water exchange in the study area after simulation outcome in December 2002 and the cross sections of selected locations in order to compare the groundwater fluctuations.





B
B'
Mekong River
Cross section B-B' with Bedrock
Bedrock
(2a)
Elevation [m ASL]
Distance from Mekong River [m]
Groundsurface
Mekong River
Flooding period
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Cross section B-B' without Bedrock
(2b)
Elevation [m ASL]
Distance from Mekong River [m]

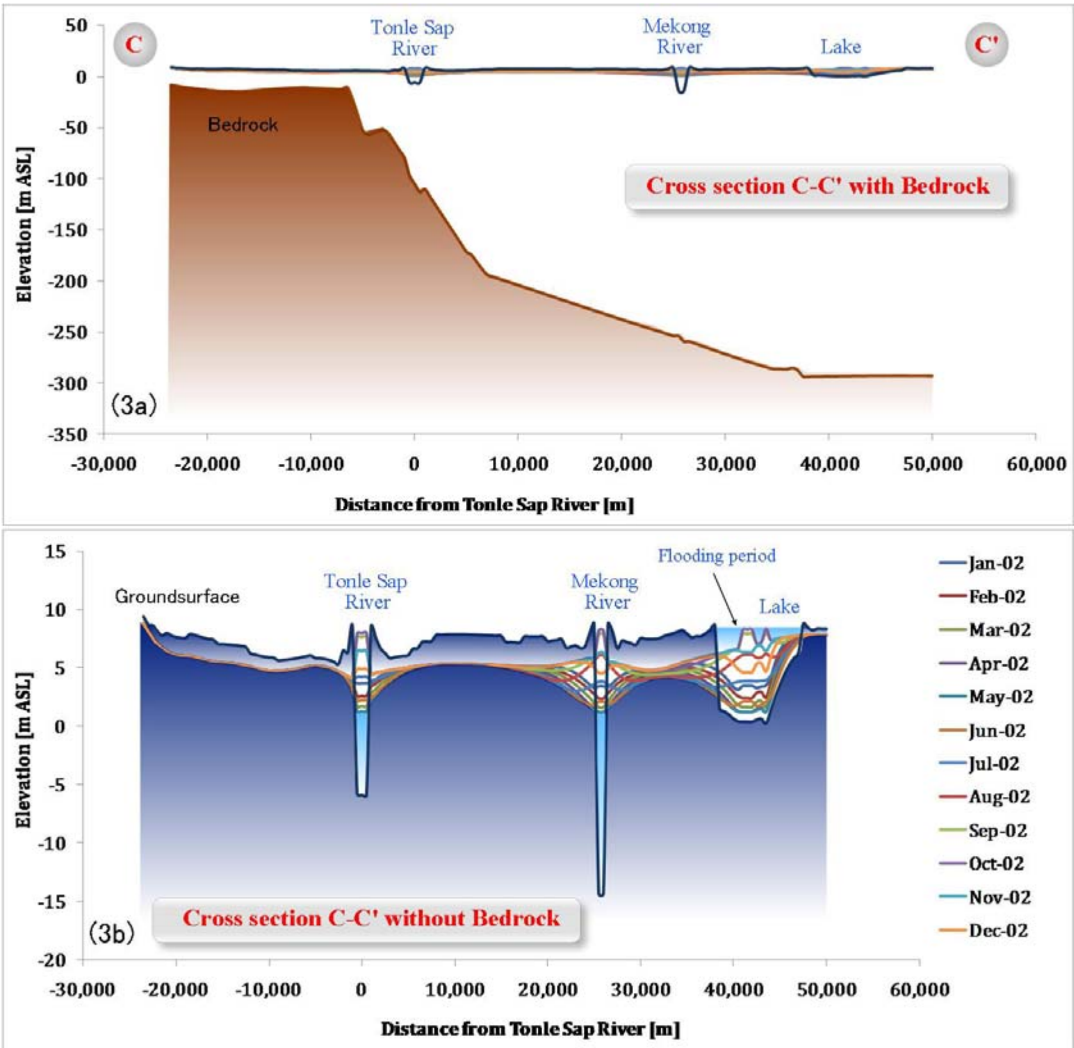


Fig. 11 Cross section showing the fluctuation of groundwater and river water in 2002 from the numerical simulation results **(1)** cross section of A-A' along Tonle Sap River **(2a & b)** cross section of B-B' along Mekong River at the northeastern part of the model area and **(3a & b)** cross section of C-C' along Bassac and Mekong River at the southern part of model area.

5. Conclusion

The numerical model of groundwater flow shows the reasonable agreement between field observation and calculation results, and it was applied for figuring out the regional groundwater flow in the study area as well by coupling the groundwater recharge model and considering the river water level. The output of numerical simulation was utilized to understand the surface water and groundwater interaction by considering the variation of groundwater and river water levels. Tonle Sap River and Mekong River from upstream to Phnom Penh is a gaining stream from the groundwater at the mountainous and hilly area during rainy and dry seasons. Bassac River and Mekong River from Phnom Penh to downstream has two functions: gaining stream during dry season and losing stream during raining season. The delay process between groundwater and river water occurred within 3 months. Groundwater and river water flow exchange zone was made in order to indentify the most vulnerable place to any pollutant. Moreover, the zonation will be helpful for the detail study. Three cross-sections in the study area were identified. Cross-section A-A' and B-B' are along Tonle Sap River and Mekong River at the upper part respectively where the aquifers supply the water to the river for both seasons. Cross-section C-C' located along Bassac and Mekong River at the lower part where the aquifers supply the water to river during dry season, and river supply the water to the aquifer during rainy season. Finally, this study is revealing the important phenomena of groundwater system in the Mekong Delta Basin especially in Cambodia.

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