Groundwater Recharge in the Irrigated Upstream Area of the Regulating Gate in the Lower Nam Kam River, Thailand

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ABSTRACT: There is soil salinity problem in northeastern Thailand. Particularly, in the lower Nam Kam River which is a branch of the Mekong River, have salinity problem in groundwater. Then, farmers cannot get agricultural water in the dry season. Because water level in the Mekong River is highly change in the dry and wet seasons. Royal Irrigation Department(RID) make a plan to set a regulator in the Nam Kam River to control water level before flowing to the Mekong River and build a reservoir in the lower part of this river basin. As the results, a reservoir existing in the lower Nam Kam River area through the year, and infiltration volume in this area will be increased by ponded water in this reservoir. This is caused by the Nam Kam control gate operation.The authors observed continuously groundwater levels in shallow aquifer over 7 years. And we have collected land use crop pattern, water levels and climate data in the Mekong and the Nam Kam River. Moreover, we have observed infiltration capacity 54 points and made the distribution map of infiltration capacity in this area. Using these data, the authors calculated the infiltration rate change during these periods. This paper shows those results and estimates the influence to groundwater level by setting the control gate in the lower Nam Kam River.

KEYWORDS: recharge, groundwater, infiltration

1. INTRODUCTION

Most area of northeastern Thailand is facing to soil salinity problem and salt deposit is found during the dry season. It is estimated that 6,650 km^2 of the land there is affected by soil salinity. Out of this amount, more than 50 percent (3,325 km^2) is found to have salt deposit. Besides, 0.3648 and 0.0048 km^2 are found to have salt deposit for 10-50 and 1-10 percent, respectively. All of these areas are in 30 out of 82 basins in northeastern Thailand (Trinet, Trinet, and Mekprougsawong: 2007).

The lower Nam Kam basin of Nakhonpanom province has the problem in lack of water due to sandy loam soil. Besides, farmers, there have to rely on groundwater for agricultural proposes, particularly during the dry season. Most of the farmers there face the problem in soil salinity and salt deposit is found during the dry season. Thus, the Royal Irrigation Department (RID) makes a decision to propose a Nam Kam basin development project in Sakonnakorn and Nakhonpanom provinces.

This study focused on the investigation of groundwater recharge rate by using the natural method before the regulating gate construction and the distribution of groundwater recharge. This aimed to find shallow groundwater recharge rate for comparing it before and after the regulating gate construction. The researchers had computed changes and infiltration/ ground water recharge rate to estimate an affect and influence on Nam Kam regulating gate management and service. This could be a model and data reference in surface water use in the area having soil salinity in the future. Meanwhile, it could be supporting data for water management of the regulating gate in the lower Nam Kam river.

2. STUDY AREA

Nam Kam basin is located in tropical monsoon area having an average amount of rainfall for 1,500-2,000 mm. per year. At Na Kae meteorology station, an average amount of rainfall is 1,500 mm. per year and 80 percent is found during April-September. However, lack of water occurs due to the uncertainty of the amount of rainfall. An average temperature there is 31.1 ◦c, the highest is 33.4 ◦c in April and the lowest was 14.4 C in June. An annual amount of evaporation is about 1,740 mm. which is higher than the amount of rainfall for about 16 percent. Main surface water source in this area is Nam Kam river (Mekprueksawong et.al.: 2008).

Fig. 1. Location map of the study area

The highest amount of water usually occurs in September (393.7 million cubic meters and the lowest is found is February (9.93 million cubic meters). There is a limitation of groundwater use in this area because only shallow groundwater can be consumed whereas dup groundwater contains a high proportion of minerals which can be used for agricultural purposes (Royal Irrigation Department: 2006).

Most area of lower Nam Kam basin has rock salt with 5-10 slope to the north and it is about 90-200 meters below the top soil. It is usually found that there is salty water infiltrating in sand layer, sand sediment, clay, and sandstone. The surface water level of fresh water, brackish water, and salt water is found at 30-40 meters below the top soil.

3. DATABASE

The researcher collected the following related data: an amount of rainfall, need for water of plants, level of surface water, level of flood, level of groundwater, and rate of water leak out. Besides, a set of questionnaires on water use of farmers in Nam Kam basin was prepare for data collection and the preparation of the geo-information database system as shown Figure 2.

3.1 Data collection

3.1.1 An amount of rainfall

Data were collected from 3 out of 5 meteorology stations in the study area: 24022

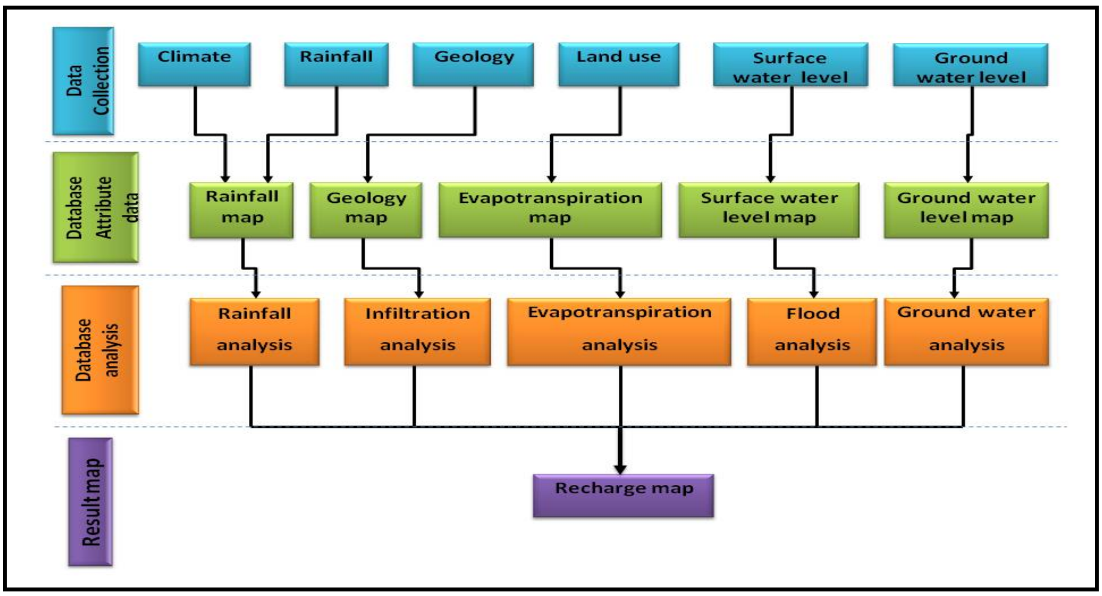

Fig. 2. Frame work Database of the applied GIS

3.1 Data collection

3.1.1 An amount of rainfall

Data were collected from 3 out of 5 meteorology stations in the study area: 24022 station (Thatpanom district), 24032 station (Na Kae district), and 24182 station (Renunakhon district) as shown in figure 3.

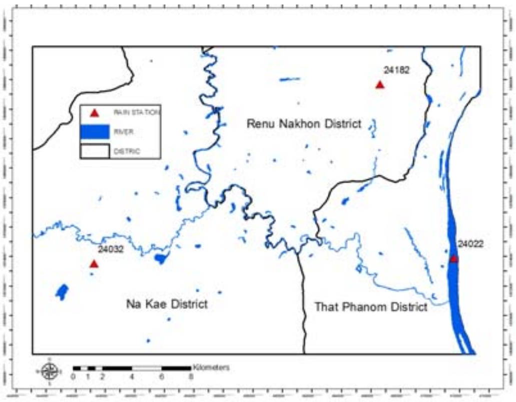

Fig. 3. Rainfall station

3.1.2 An amount of water

The team of researchers collected data on water level measuring and water flow rate in the study area as shown in Figure 4. However, it was found that the current condition of water amount and level measuring has been changing from the past due to the construction of regulating gates in Nam Kam river (Na Khoo gate) and Nam Bang river (Na Bua gate). It aimed to keep and elevate water level supplying to agricultural areas along the rivers. This made an amount of water discharging to these areas was not in nature because it depended on water flow control by the regulating gates. Besides, there was the construction of lower Nam Kam regulating gate making most water amount and level measuring stations close. Based on the investigation, it was found that the following stations were left: Kh69A (Nam Kam river), Kh68 (Nam Bang and Nam Kam river were constructed, an amount of water discharge from lower regulating gates could be computed based on the Calibrate – width of opened leaf of the gate and level of water in the front and the back of the regulating gated. However, the regulating gates still had no Calibrate making the computation cannot be done; only the water level in the front and at the back of the regulating gates could be recorded

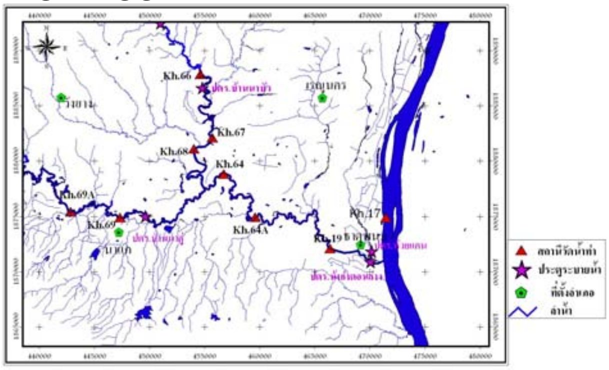

Fig. 4. gauging station

3.1.3 Investigation of running water condition

An amount of running water or flood in the study area could infiltrate into the soil. Thus, the amount of water infiltrating into the soil was depend on flood time span, flood area, and infiltration rate. This amount of infiltration rate would be recharge date further used in the MODFLOW model. In this investigation, the team of researcher used running water data of irrigation agencies in Thailand (Chuenchooklin: 2006).

3.1.4 Land use and agriculture

According to the 2004 land use map of Land Development Department, it was found that cultivation in the study area was mostly under rainfed condition (342,000 rai or 60%). This was followed by forest area (18%) and 7 percent could access to irrigation. For other types of land use, the area expected to be flooded due to water storage of regulating gates in lower Nam Kam basin was mostly eucalyptus plantation area (Figure 6).

Based on the field survey, it was found that farmers in the study area grew rice as a main plant and the rest were fruit trees (mango and orange) and perennials (rubber and eucalyptus). Besides, very few crop plants were found there. After rice harvesting, most part of the study area was abandoned due to lack of water source. Very little groundwater was used for agricultural purposes.

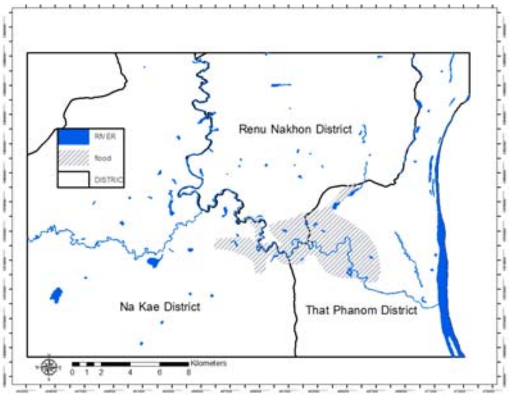

Fig. 5. Flood area

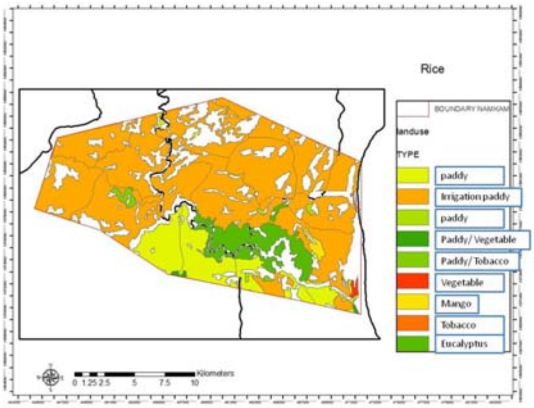

Fig. 6. Land use

3.1.5 Examining infiltration rate

Infiltration rate examining was conducted in 54 sites (Figure 7) before Nam Kam regulating gate began to operate. This aimed to compare with the data on filtration rate after the operation of the regulating gate.

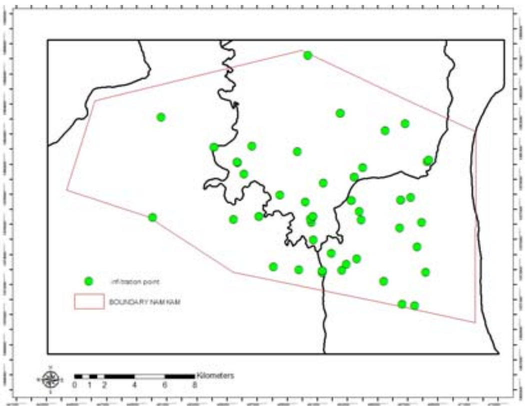

Fig. 7. Infiltration point

3.2 Output from attribute data

For further data analysis, the team of researchers needed to use all basic data to be a data based in the form of geo-information system. Program ARC GIS 9.1 was used for building the geo-information system (Figure 3, 4, 5, 6, 7).

4. METHODOLOGY AND METHODS

4.1 Finding need for water of plants (crop water requirement)

$$ET_c = K_c \times ET_p \qquad \textbf{(1)}$$

Where

ET_C = Need for water of plants (mm./day)

K_c = Coefficient value of water use by the plants

ET_p = An amount of water used by the plants (mm./day)

4.2 Finding and amount of rainfall

Thiessen Method was employed based on an amount of rainfall obtained from each rainfall measuring station. The determination of area around the rainfall measuring station was done based on Thiessen Polygon.

$$\bar{P} = \frac{P_1A_1 + P_2A_2 + ... + P_nA_n}{A_1 + A_2 + ...A_n} \qquad \textbf{(2)}$$

Where

P_1 = An average amount of rainfall at sub-basin 1

P_n = An average amount of rainfall at sub-basin n

A_n = Area of sub-basin n

4.3 Infiltration

The movement process of infiltration would increase moisture in the soil which was beneficial to plants for water uptake. Besides, it was beneficial to groundwater accumulation during the rainy season and groundwater use in the dry season.

4.3.1 Examining infiltration properties by using Double Ring Infiltration Method

This method was employed for finding filtration rate (Hydraulic Conductivity of the Surface Layer). Two metal cylinders with at least 0.08 inch in thickness, and open ended were used. The diameter of the outer cylinder must be greater than that of the inner cylinder for at least 8 inches. The inner cylinder had at least 12 inches in diameter and 12-14 inches in length. The outer cylinder was hammered into the soil for 2 inches and then the inner cylinder was hammered into the soil for 4 inches. A plank with 1 inch in thickness and 5-6 inches in width was placed on the two cylinders and then it was hammered little by little. Then, a level measuring instrument was used for examining the level of orifice of the cylinders. After that, poured water into the outer cylinder until it was 3 inches above the soil surface. Then, poured water immediately into the inner cylinder until it was 3 inches about the soil surface. Then measured the distance from the orifice of the inner cylinder to the water level and timing was conducted. Kept on pouring water into the outer cylinder which it could be observed that its water level decreased more rapidly than that of the inner cylinder. The water level was measure every 1, 3, 5, 10, 20, 30, 45, 60, 90, 120 minutes and every next hours. An appropriate time for water level measuring differed based on infiltration rate. Generally, it must not infiltrate for more than 1 inch of each measuring time. When the water level was at 1 inch, poured water again until it was 3 inches in height.

4.3.2 Equation for finding filtration rate (seepage capacity)

The team of researchers used the equation as shown below

$$AC = \frac{I}{H} \qquad \textbf{(3)}$$

Where

Ac = Seepage capacity (mm/day/m)

I = Infiltration rate from the equation (Horton, 1939) (mm/day)

H = Water depth per unit of remaining water depth above soil surface (m)

Similar to infiltration capacity, the seepage capacity decrease with time and nearly constant at some value, called "seepage coefficient (a_c)

4.4 Natural Recharge

Groundwater systems might be termed like that of surface water systems, i.e. inputs, outputs, and storage. The significant difference was: water infiltration through soil layers to artesian well water level. The team of researcher used the following equation:

1) In the case of there was no flood in the area

$$Q = (Q_R - ET_c) \times AC \qquad (3)$$

2) In the case of the was fold in the area

$$Q = Q_F \times AC \qquad (4)$$

3) In the case of there was no rain and flood in the area and there was no cultivation in the area

$$Q = 0$$

Where

Q = Recharge (m^3/month)

D_R = An amount of rain (mm./month)

ET_C = Crop water requirement (mm/month)

AC = Infiltration rate (mm./month/m)

D_F = Height of flood level (m./month)

D_P = Height of water level in the rice field (m/month)

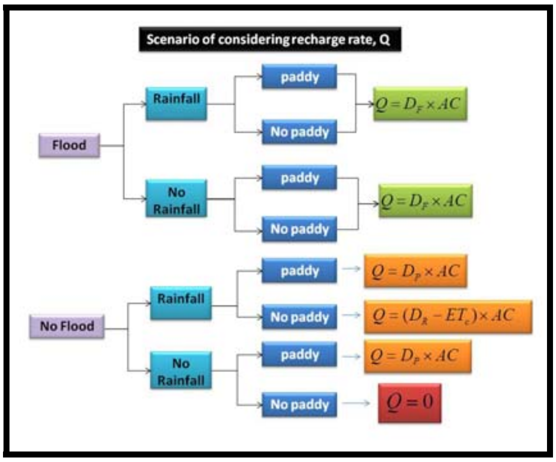

Fig. 8. Scenario of considering recharge rate,Q

Table 1 Data Analysis on crop water requirement

	ETp(mm/month)				
MONTH	**rice (irrigated area)**	**rice (non irrigated area)**	**tomato**	**Vegetable**	**Tobacco**
JAN	200.00	0.00	95.55	118.44	113.40
FEB	200.00	0.00	109.20	135.36	129.60
MAR	0.00	0.00	131.04	162.43	155.52
APR	0.00	0.00	0.00	0.00	0.00
MAY	100.00	100.00	0.00	0.00	0.00
JUN	200.00	200.00	0.00	0.00	0.00
JUL	200.00	200.00	0.00	0.00	0.00
AUG	200.00	200.00	0.00	0.00	0.00
SEP	200.00	200.00	0.00	0.00	0.00
OCT	50.00	0.00	0.00	0.00	0.00
NOV	0.00	0.00	0.00	0.00	0.00
DEC	150.00	0.00	88.73	109.98	105.30

Table 2 Data Analysis on Infiltration (mm/d/m)

ID	**Infiltration AC(mm/d/m)**	**ID**	**Infiltration AC(mm/d/m)**	**ID**	**Infiltration AC(mm/d/m)**	**ID**	**Infiltration AC(mm/d/m)**
ow8	23.9	7	46.2	1	94.8	DR-12 n	50.8
if2	242.7	8	110.3	2	320.2	DR-13 n	1653.6
if1	14.7	10	48.7	3	820.6	DR-14 D	143.8
a3	1.6	11	50.1	5	1866.3	DR-15 P	108.8
a1	51.8	infil1	122.8	6	8.4	DR-16	1190.4
a2	0.7	if1	1457.5	7	46.2	DR-17 O	117.1
i-1	3.9	if3	409.3	8	110.3	DR-18 O	3206.5
a4	4.2	i-1	122.8	10	48.7	DR-20	744.5
dm1-1	35.1	i-2	594.4	11	50.1	DR-21 O	1167.2
dm6-1	9.4	i-3	469.3	DR-02 o	787.2	DR-22	197.3
dm2-2	75.1	i-4	106.2	DR-03	325.2	6	8.4
dm3-3	29.3	i-5	62.0	DR-05 O	50.9	dm2-4	799.9
dm9-1	42.9	dm1-1	35.1	DR-06 n	1526.7	DR-11 O	1375.0
dm6-2	55.7	dm2-2	75.1	DR-07 N	1234.5		
dm6-3	14.2	dm2-1	384.7	DR-08 N	1175.1		
dm1-2	37.6	dm3-1	769.5	DR-09	3662.0		
1	94.8	dm3-2	317.0	DR-10 N	167.0		

Table 3 Rainfall (2009) (mm/month)

	STATION		
MONTH	24022	24032	24182
JAN	4.40	10.70	11.00
FEB	20.30	61.70	51.90
MAR	3.50	8.10	0.00
APR	59.00	97.50	28.00
MAY	306.70	253.00	324.70
JUN	156.50	71.10	109.60
JUL	259.80	196.30	326.30
AUG	411.80	214.70	270.90
SEP	105.00	0.00	231.60
OCT	153.50	118.20	127.30
NOV	0.00	0.00	0.00
DEC	0.00	0.00	0.00

5. DATA ANALYSIS

Based on figure 8, it is the specifications on the equation selection used in the study area. Data on an amount of rainfall need for water of plants in flood area were replaced in the equations. The monthly water adding maps are shown below.

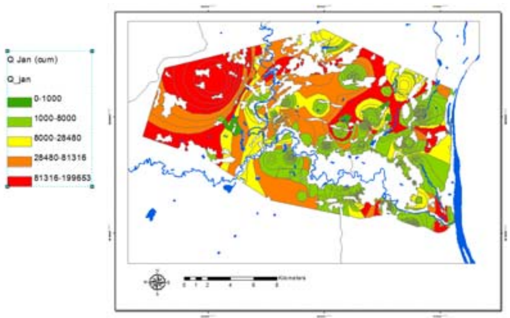

Fig. 9. Recharge (January)

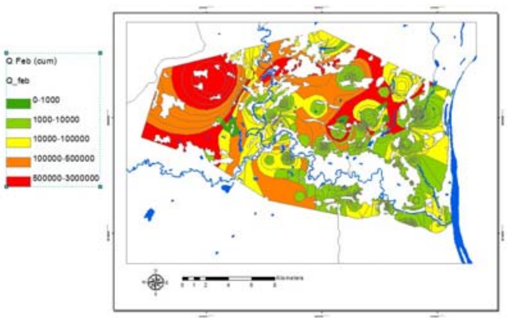

Fig. 10. Infiltration (February)

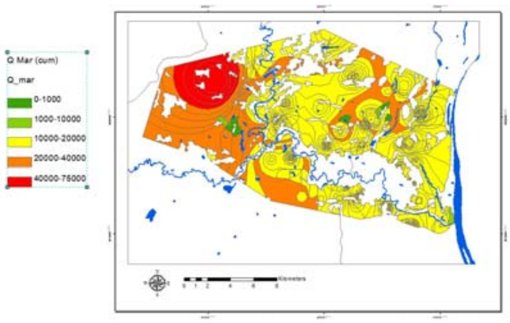

Fig. 11. Recharge (March)

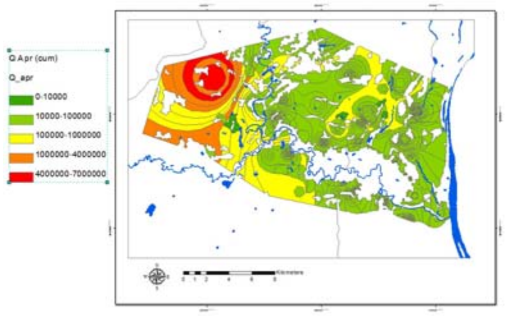

Fig. 12. Recharge (April)

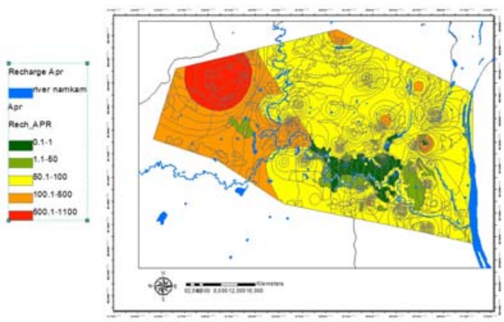

Fig. 13. Recharge (May)

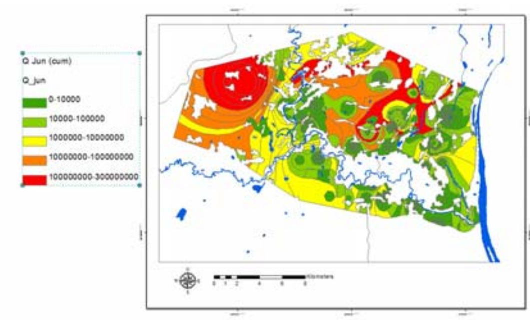

Fig. 14. Recharge (June)

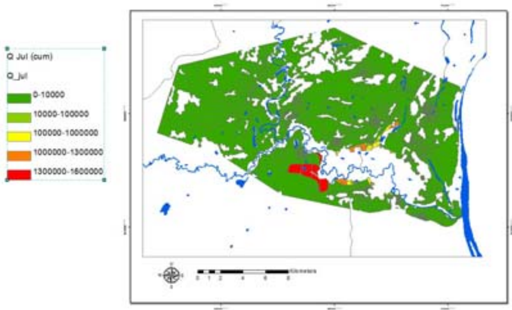

Fig. 15. Recharge (July)

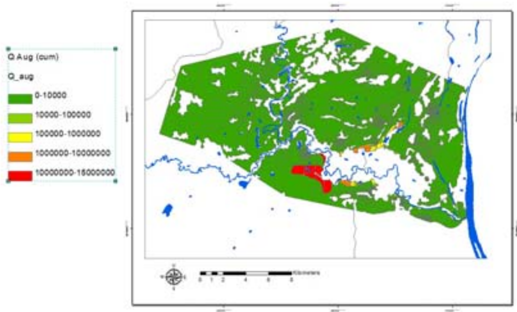

Fig. 16. Recharge (August)

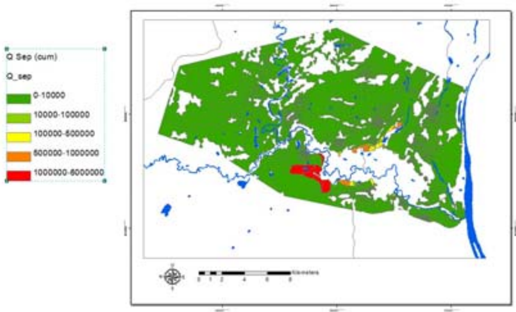

Fig. 17. Recharge (September)

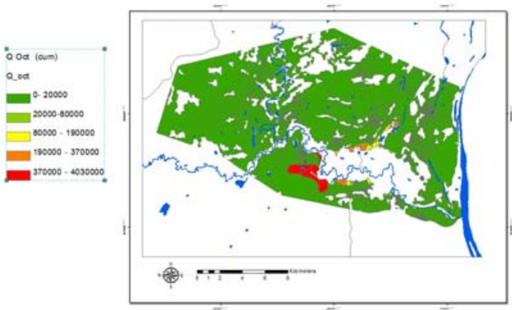

Fig. 18. Recharge (October)

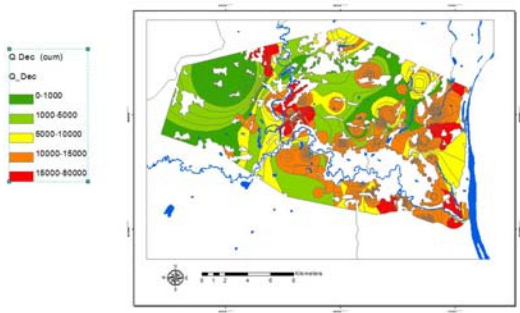

Fig. 19. Recharge (December)

6. CONCLUSIONS

Figures 9-19 shows recharge in the study area. It can be seen that high recharge occurred in the dry season and covered almost the whole area. In the rainy season, however, recharge was clearly low.

Aside from an amount of rain as a main factor controlling an amount and level of artesian well water, there were other factors controlling it, e.g. during rice growing time most water was in the zone of soil moisture which it was up taken by plants and the rest flew into the zone of saturation and became to be artesian well water. Since the infiltration rate was low, most water flew to bodies of surface water, e.g. stream, canal, river, etc. and it was called as 'runoff'. Therefore, not heavy rain but with high frequency could provide water to the artesian well water system rather than heavy rain in slope areas. In the case of few cover plants or the property in low level of infiltration, it had a high effect on an amount of water infiltrating into the soil. However, part of runoff water in bodies of surface water infiltrated into the artesian well water system.

REFERENCES

Chuenchooklin, S., et al, 2008. Recently flood events and groundwater relationship in lower nam kam basin,Thailand, Proc*:* *5th Annual Meeting AOGS200*, Busan, Korea.

Mekprougsawong, P., et el., 2008. Analysis of groundwater condition in irrigated area of lower nam kam control gate project. 3rd THAICID national symposium, Bangkok, Thailand.

Royal Irrigation Department, Thailand., 2006. Study and development on geology and hydrogeology. Lower nam kam irrigation project by Chaingmai university.

Trinetra, k., Trinetra Y., Mekprougsawong, P., 2007. Study reports of lower nam kam irrigation project, Nakhon pranom province, Thailand.