*Research article*

# Evaluation of On-Farm Pond Water Budget in Khon Kaen Province, Thailand

**KEWAREE PHOLKERN***
*Groundwater Research Center, Faculty of Technology, Khon Kaen University, Kohn Kaen, Thailand*
*Email: rekawee@hotmail.com*

**VICHAI SRIBOONLUE**
*Groundwater Research Center, Faculty of Technology, Khon Kaen University, Kohn Kaen, Thailand*

Received 19 December 2011   Accepted 7 February 2012   (*: Corresponding Author)

**Abstract** An on-farm pond is an essential technique for water resources management in northeast Thailand. It can be used for many purposes e.g. farm water supply, supplementary irrigation, livestock, aquaculture, and flood mitigation. The purpose of this research is to evaluate the suitability of two calculation methods for on-farm pond water budget. Two on-farm ponds in Ban Wangwa were selected to be the study sites and the water balance of the ponds including water inflow and water outflow components were calculated. Water inflow was determined by two methods, namely watershed routing and synthetic unit hydrograph. The results show that the synthetic unit hydrograph method gives the better agreement to the observed data than the watershed routing method in both of peak discharge and runoff volume. The main causes of water losses are evaporation, water usage, and seepage. Evaporation from the ponds was determined by two methods, namely the Penman method using Priestley-Taylor evaporation equation and the Evaporation pan method. Subsequently coefficient of the Priestley-Taylor evaporation ($\alpha$) and coefficient of the evaporation pans ($K_p$) are 1.66 and 0.88, respectively. The evaporation by pan evaporation is fast, simple and easier than Priestley-Taylor evaporation.

**Keywords** on-farm pond, water budget, inflow, evaporation

## INTRODUCTION

An on-farm pond is an appropriate technology for water harvesting in northeast Thailand. The undulating landscapes, which dominate the northeast topography, enhance the efficiency and usability of on-farm ponds, by providing catchment areas and reasonable head for water conveyance. It can be used for many purposes e.g. farm water supply, supplementary irrigation, live stock water consumption, aquaculture, and even flood mitigation (Suresh, 2002; Ngigi et al., 2005; Yoo and Boyd, 1994; and Kumar, 1992).

The climate of the northeast is monsoon, where wet season is from May to October and dry season is the rest of the year. Therefore more than 80% of annual rainfall is in the wet season, on-farm pond harvests water during 6 months of the wet season and supplies water for the next dry 6 months. The study of the nature of the on-farm pond inflow and outflow is important for the on-farm pond design, construction, and management. To utilize an on-farm pond to its highest potential and in an environmentally sound way, its study of water balance must be performed. This study presents a suitable method for calculating the pond water inflow and water loss of the on-farm ponds.

## STUDY AREA

The study areas located at two on-farm ponds in Ban Wangwa, 25 km south of Khon Kaen, were chosen as study sites. The two ponds are closed together, and one is considered to be the north pond while the other is considered the south pond. The north pond has the dimensions of 20×30×4 m. Its elevation of the bottom is 194.44 m above the mean sea level. The south pond has the size of 17×33×4 m and the elevation of the bottom is 194.95 m amsl. Fig. 1 shows the satellite image of the ponds and their environment which consists of upland crops, fallows, and eucalyptus woodlands.

The surrounding topography of the two ponds was surveyed using a level and a hand-held GPS. The topographic contours and the watershed areas of the two ponds are shown in Fig. 2. The catchment of the north pond is like a butterfly in shape which should produce a sharp peak with a short time base. The catchment of the south pond is an elongated shape that should produce a mild peak with a long time base. The outlet from the watershed or the inlet into the pond for each of the cases is quite special. For the north pond, the inlet is at the northeast corner of the pond and close to the road, therefore we installed a rectangular weir for inflow measurement. For the south pond, the outflow from the watershed passes through a ditch which leads across a road to the pond, a complicated inflow arrangement. The length and slope of the main channel for the north pond are 167 m and 0.0096 respectively, and for the south pond are 480 m and 0.0165 respectively. The areas of the watershed of the north and the south pond are 10643 m$^2$ and 12618 m$^2$ respectively. Piezometers were installed to observe groundwater levels, two for the north pond at $P_2$ and $P_4$ in Fig. 2 and one for the south pond at $P_5$. Automatic water level recorders were installed on north and south ponds at $P_3$ and $P_6$ respectively. An automatic weather station was set up near the north pond. It recorded rainfall, air and dew point temperatures, relative humidity, wind speed and direction, and net radiation.

## METHODOLOGY

Water balance equation or continuity equation can be used to describe the flow of water in and out of pond. Using all components that might possibly be significant, solve the continuity equation for groundwater seepage (Chow, et al., 1988) as equation (1).

$$\mathrm{P} + \mathrm{R_i} + \mathrm{G_i} - \mathrm{E} - \mathrm{R_o} - \mathrm{G_o} - \mathrm{U} = \frac{\Delta \mathrm{S}}{\Delta \mathrm{t}} \tag{1}$$

where P is precipitation, $\mathrm{R_i}$ and $\mathrm{R_o}$ are Runoff in and out respectively, $\mathrm{G_i}$ and $\mathrm{G_o}$ are Groundwater seepage additional to the pond and removal respectively, U is water use and $\Delta\mathrm{S}/\Delta\mathrm{t}$ is change in storage.

Water balance in the on-farm pond was divided into two main sections. First section is the evaluation of accuracy of the water harvesting or water inflow of the on-farm ponds. The second section was conducted to calculate the factors affecting water loss or outflow of the on-farm ponds.

### (1) On-farm ponds water harvesting

The water which flows into the pond consists of rainfall in to the pond, runoff and groundwater inflow. The main component of water inflow is runoff. Two simple lump models were used in this study, namely the watershed routing technique and the synthetic unit hydrograph method.

### The watershed routing technique

Based on the assumption that the outflow from the watershed varies nonlinearly with the storage in the watershed, van den Akker and Boomgaard (1996) suggested the following model.

$$q_2 = \frac{k - 0.5\Delta t}{k + 0.5\Delta t} q_1 + \frac{\Delta t}{k + 0.5\Delta t} i \tag{2}$$

where $q_1$ and $q_2$ are discharges as depth per unit time at time steps 1 and 2 respectively, i is intensity of excess rainfall, k is parameter and $\Delta t$ is time interval.

The watershed routing model can be used to predict the flow rate from the present flow rate and intensity of rainfall data. The unit flow rate, q, can convert to total flow rate, Q, by multiplying with the watershed area.

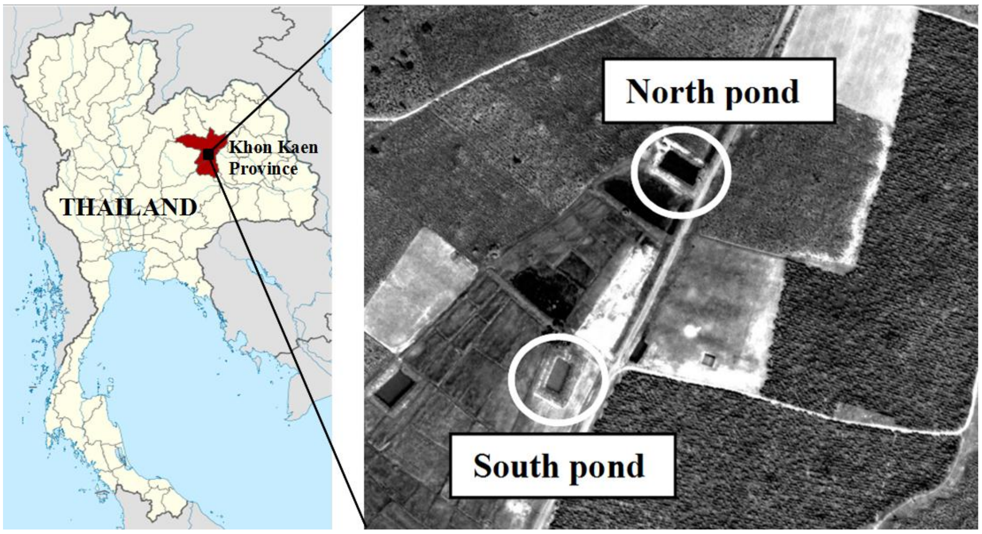


**Fig. 1 Location of the two experimental ponds satellite image**

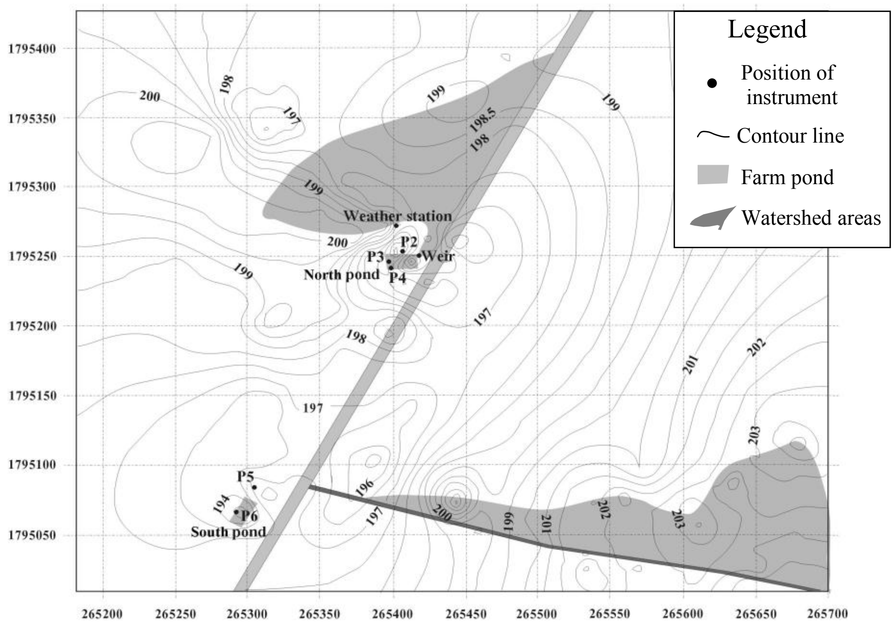


**Fig. 2 Location watershed areas and its environment**

## The synthetic unit hydrograph

The unit hydrograph is a direct runoff hydrograph resulting from a unit rainfall (1 cm depth) of the specific rainfall duration (Shaw, 1994). The unit hydrograph is normally derived from records of rainfall and runoff data. When dealing with small watersheds, coupled rainfall and runoff data are hardly available, we therefore resort to the synthetic unit hydrograph. The unit hydrograph that is synthesized from topographic and climatic features is called a synthetic unit hydrograph (Shaw, 1994).

The shape of a unit hydrograph may be assumed as the gamma function distribution (Aron and White, 1982). Akan and Houghtalen (2003) suggest an equation for coordinate of unit hydrograph as equation (3).

$$u = \frac{C_p A}{t_p}[(t/t_p)\exp(1-(t/t_p))]^{n-1} \tag{3}$$

where $C_p$ = proportional constant, $t_p$ = time to peak discharge, A = watershed area, t = time, u = unit discharge at time t and n is a constant which related to $C_p$ as equation (4).

$$n = 1.0685 + 0.1175C_p + 0.782C_p^{\ 2} \tag{4}$$

We selected 3 prominent storm events, two storms in the year 2006 on 30 Aug, and 17 Sept, and one storms in the year 2007 on 12 Sept for this study. The runoff data were interpreted from the incremental volume of the pond storage with the time interval of recording. Table 1 shows the data of rainfall and runoff for the north and the south pond.

**Table 1 The data of rainfall and runoff into the north and the south pond**

| Time (min) | 30 Aug 2006 | | | 17 Sep 2006 | | | 12 Sep 2007 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Rainfall (mm) | Runoff ($m^3$/s) north pond | Runoff ($m^3$/s) south pond | Rainfall (mm) | Runoff ($m^3$/s) north pond | Runoff ($m^3$/s) south pond | Rainfall (mm) | Runoff ($m^3$/s) north pond | Runoff ($m^3$/s) south pond |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 0.20 | 0.005 | 0 | 0 | 0 | 0.031 | 0 | 0 | 0 |
| 20 | 3.80 | 0.004 | 0.006 | 2.60 | 0.012 | 0.008 | 8.2 | 0.004 | 0.007 |
| 30 | 10.60 | 0.056 | 0.023 | 4.00 | 0.044 | 0.017 | 2.2 | 0 | 0.002 |
| 40 | 4.60 | 0.060 | 0.044 | 7.20 | 0.034 | 0.011 | 3 | 0.016 | 0.005 |
| 50 | 3.00 | 0.049 | 0.061 | 4.80 | 0.029 | 0.019 | 7.2 | 0.047 | 0.028 |
| 60 | 0.60 | 0.024 | 0.077 | 4.40 | 0.023 | 0.011 | 7 | 0.016 | 0.033 |
| 70 | 0.80 | 0.002 | 0.022 | 1.60 | 0.026 | 0.036 | 1 | 0.026 | 0.018 |
| 80 | 0.60 | 0.008 | 0.022 | 2.00 | 0.025 | 0.014 | 0 | 0.022 | 0.024 |
| 90 | 0.60 | 0 | 0.013 | 0.60 | 0.006 | 0.014 | 0 | 0.019 | 0.029 |
| 100 | 0.60 | 0.004 | 0.008 | 0.20 | 0.005 | 0 | 0 | 0.013 | 0.015 |
| 110 | 1.20 | 0.009 | 0.022 | 0 | 0.001 | 0.008 | 0 | 0.010 | 0.009 |
| 120 | 1.60 | 0.013 | 0.004 | 0.20 | 0.001 | 0.006 | 0 | 0.008 | 0.004 |
| 130 | 0.60 | 0.002 | 0 | 0 | 0 | 0 | 0.2 | 0.007 | 0.003 |
| 140 | 0 | 0.008 | 0.008 | 0 | 0 | 0 | 0 | 0.007 | 0 |

**(2) Water loss or outflow**

The outflow of water or water loss from a pond, consists of evaporation, water use and groundwater seepage. The query found that both on-farm ponds are not water used for any activity. Groundwater seepage can be determined from the water balance equation or continuity equation. This study presents a method to determine water loss from evaporation, that water loss is the factor of most important (Vichai, 2008).

In the design and management of the reservoir, evaporative water loss is the factor of most important (Vichai, 2008). The most popular method for determining the amount of evaporation, Penman equation (1948) was employed. Penman equation combines the energy balance with the mass transfer method and derives an equation to compute the evaporation from open water. Penman equation is quite difficult to be calculated and requires a lot of information. Then pond evaporation data was estimated by Penman equation by using variables of other evaporation equation that was more simple, as follows.

**Priestley and Taylor evaporation equation**

In 1972, Priestley and Taylor have revised the penman equation to be calculated easier as the Priestley and Taylor evaporation equation (5).

$$E_{pond} = \alpha \frac{\Delta}{\Delta + \gamma} E_r \tag{5}$$

where $E_{pond}$ = pond evaporation, $\Delta$ = gradient of the saturated vapor pressure curve at air temperature, $E_r$ = evaporation rate, $\gamma$ = psychrometric constant.

$\alpha$ is unknown parameter value. There will be slight variations in location of the study area. Determining evaporation by Priestley and Taylor evaporation equation is much easier than Penman equation.

**Evaporation pan**

The general methodology for evaporation calculation is the evaporation pan ($E_p$). There are various types of evaporation pan. Adjustment factors or pan coefficients ($K_p$) have been determined to convert the data recorded in evaporation pans so that they correspond to evaporation from large open water surface. Equation of the evaporation pan (Chow, et al., 1988) is as equation (6).

$$E_{pond} = K_p E_{pan} \tag{6}$$

The evaporation from the pond was computed by using data from an automatic weather station, which was set up on the study area in dry season of year 2006 and 2007 (November 2006 to April 2007). Evaporation pan ($E_{pan}$) data of study area from Thai Meteorological Department was used.

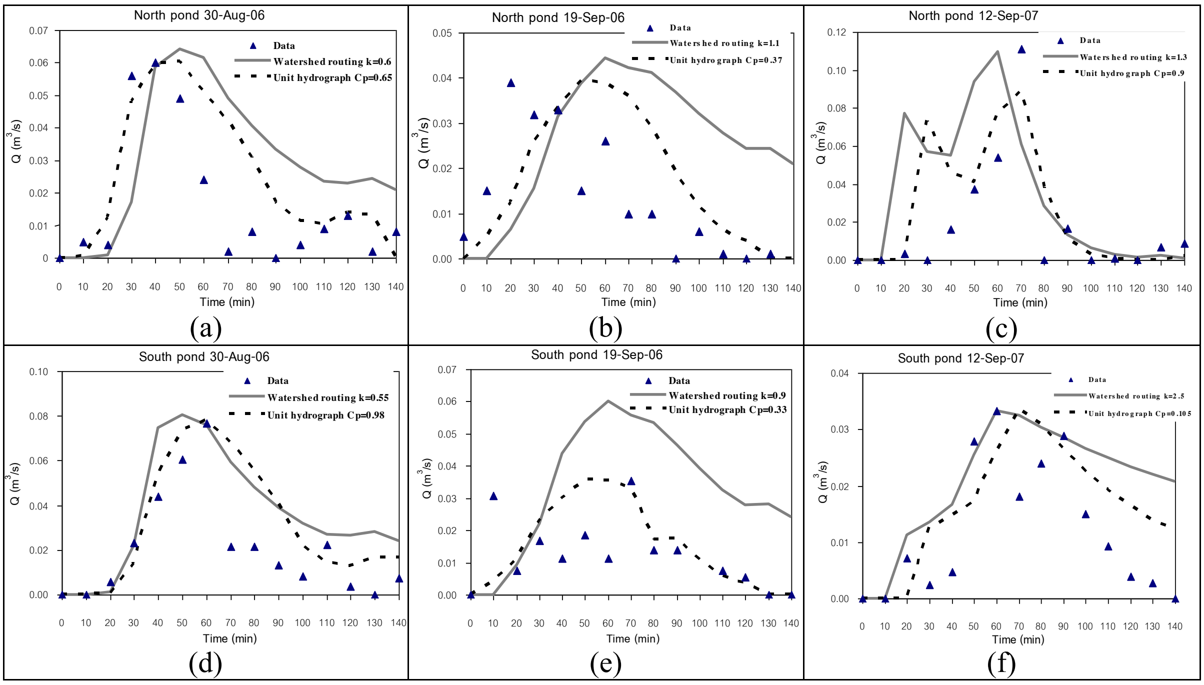


**Fig. 3 Comparison of the predicted runoffs to the observed data, (a), (b), and (c) for the north pond and (d), (e), and (f) for the south pond**

## RESULT AND DISCUSSION

Three sets of rainfall-runoff data on 30 Aug and 19 Sept, 2006 and 12 Sept, 2007 were used. The observed hydrographs were plotted and compared with the two predicted methods in Fig. 2. It is clear from Fig. 3 that the synthetic unit hydrograph method has better agreement with the observed hydrograph than the watershed routing technique. For peak discharge, the synthetic unit hydrograph method gives lower values that are closer to the observed data than the routing technique, although not by much. However, for the volume of flow, the watershed routing technique predicted much larger volumes than the observed data or the unit hydrograph method.

The k values vary in the ranges 0.6-1.3 and 0.55-2.5 for the north and the south pond respectively. The coefficient $C_p$ values of the synthetic unit hydrograph are in the ranges 0.37-0.90 and 0.10-0.98 for the north and the south pond respectively. The variations in both k and $C_p$ demonstrate the nonlinearity of the flow system. The average values of k of both ponds are rather varied, but $C_p$ of both ponds are fairly close. It is suggested that the runoff calculation from rainfall for an on-farm pond water harvesting in northeast Thailand should be done by using the synthetic unit hydrograph. The suitable $C_p$ value can be obtained by fitting the model to several observed data then averaging the values.

Evaporation of on-farm ponds, in November-February are in the ranges 4.48-4.77 mm/day, those in March and April are 5.26 mm/day and 6.03 mm/day respectively as shown in Table 1. The research results help to find the coefficients for the simpler method namely Priestley-Taylor evaporation equation and the Evaporation pans method. The average coefficient $\alpha$ values of Priestley-Taylor evaporation equation in Ban Wangwa are in the ranges 1.37-1.86 (average 1.67). The pan coefficient $K_p$ values of evaporation pans are in the ranges 0.80-0.91 (average 0.87) for Ban Wangwa.

**Table 2 Evaporation of water in the on-farm pond and the most suitable values of $\alpha$ and $K_p$**

| Month | The data of evaporation (mm/d) | $\alpha$ (Priestley and Taylor evaporation equation) | $K_p$ (Evaporation pan) |
|---|---|---|---|
| November 2006 | 4.40 | 1.37 | 0.89 |
| December 2007 | 4.34 | 1.82 | 0.90 |
| January 2007 | 4.47 | 1.86 | 0.91 |
| February 2007 | 4.80 | 1.80 | 0.85 |
| March 2007 | 5.31 | 1.50 | 0.80 |
| April 2007 | 6.04 | 1.40 | 0.85 |
| **Average** | **4.89** | **1.67** | **0.87** |

## CONCLUSION AND RECOMMENDATION

The synthetic unit hydrograph method gives better predictions than the watershed routing technique for both the peak discharge and the runoff volume. The k-values of the routing technique vary in the range 0.55-2.5 (avg 1.16). The $C_p$-values of the unit hydrograph method vary in the range 0.10-0.98 (avg 0.56). The variations in k and $C_p$ demonstrate the nonlinearity of the flow systems.

Evaporation of on-farm ponds, in November-February are in the range 4.48-4.77 mm/day, those in March and April are 5.26 mm/day and 6.03 mm/day respectively. The results help to find the coefficients for the simpler method namely Priestley-Taylor evaporation equation and the Evaporation pans method. The average coefficient $\alpha$ value of Priestley-Taylor evaporation equation is 1.66. The pan coefficient $K_p$ value of Evaporation pans is 0.88. However, the evaporation by pan evaporation is fast, simple and easier. Because the data used are less and easier to find.

## ACKNOWLEDGEMENTS

This research is funded by Japan International Research Center for Agricultural Sciences (JIRCAS) and Groundwater Research Center (GWRC), Khon Kaen University, Thailand. The authors thank Mr. Suwanchai Nadee and Mr. Phayom Saraphirom for their useful suggestions.

## REFERENCES

Aron, G. and White, E. 1982. Fitting a gamma distribution over a synthetic unit hydrograph. Water Resources Bulletin, 18(1).

Chow, V.T., Maidment, D.R. and Mays, L.W. 1988. Applied Hydrology. McGraw-Hill.

Penman, H.L. 1948. Natural evaporation from open water, bare soil, and grass, Proc.R.Soc.London A, Vol. 193, 120-146.

Shaw, E.M. 1994. Hydrology in practice. 3rd ed., Chapman and Hall.

Sriboonlue, V. 2008. Hydrology. Faculty of Engineering, Khon Kaen University, Thailand.

Suresh, R. 2002. Soil and Water Conservation Engineering. 2nd ed., Standard Publishers.

Van den Akker, C. and Boomgaard, M.E. 1996. Hydrologie. Technische Universiteit Delft, Netherland.