4th Taiwan-Japan Joint Workshop on Hydrological Research for Earthquake Prediction

# *Rainfall-induced groundwater level variation*

## *--- Unit Rainfall response*

Chyan-Deng Jan and Tsung-Hsien Chen

Department of Hydraulic and Ocean Engineering
National Cheng Kung University

- **The variation of groundwater level is a result of multi-effects including atmosphere pressure, earth tide, general diffusion, precipitation, earthquake and other irregular noises.**

**Atmosphere pressure** — **Rainfall component**

$$Y_i = C_i + \cancel{P_i} + \cancel{T_i} + R_i + O_i$$

**Groundwater level** — **Trend component** — **Earth tide component** — **Other irregular noises**

- Atmosphere pressure and earth tide component:
  - → BAYTAP-G program
    ( residual groundwater level )

- Rainfall component:
  - → Quick / Slow response separation
  - → Linear system analysis (Kernel function)

- **Unit rainfall function** for rainfall-induced groundwater level increment：

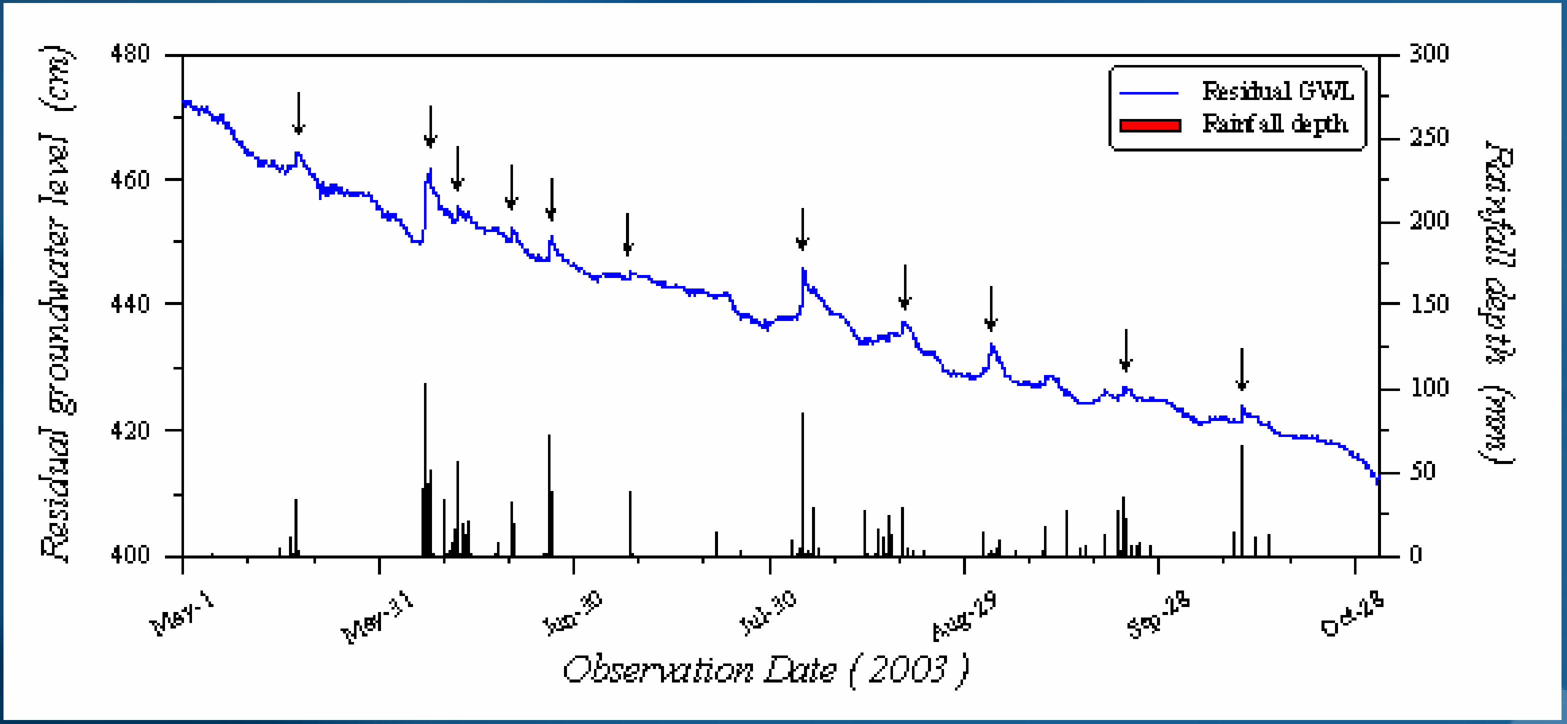
$$y(t) = \int_0^t h(t-\tau)\, x(\tau)\, d\tau$$

**Groundwater level increment** — $y(t)$

**Kernel function (unit rainfall response)** — $h(t-\tau)$

**Rainfall depth** — $x(\tau)$

➢ **Examining the data of residual groundwater levels, one could more easily to find the rainfall effect on the groundwater level variation.**

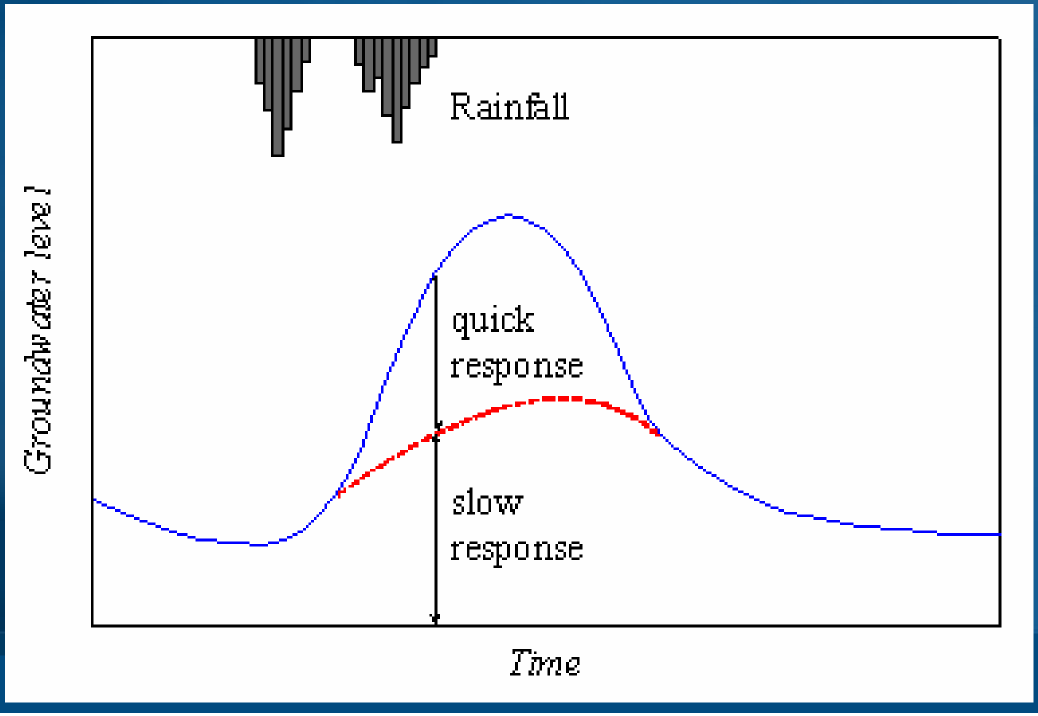



**Residual groundwater level and rainfall depth at the Naba station.**

- Rainfall effect on the groundwater level could be divided into two parts:

  **quick response** and **slow response**

- The quick rainfall response may remain few minutes to few hours, while the slow rainfall response may last few days or weeks.



## Quick / Slow response separation :

(1) Smoothed minima technique

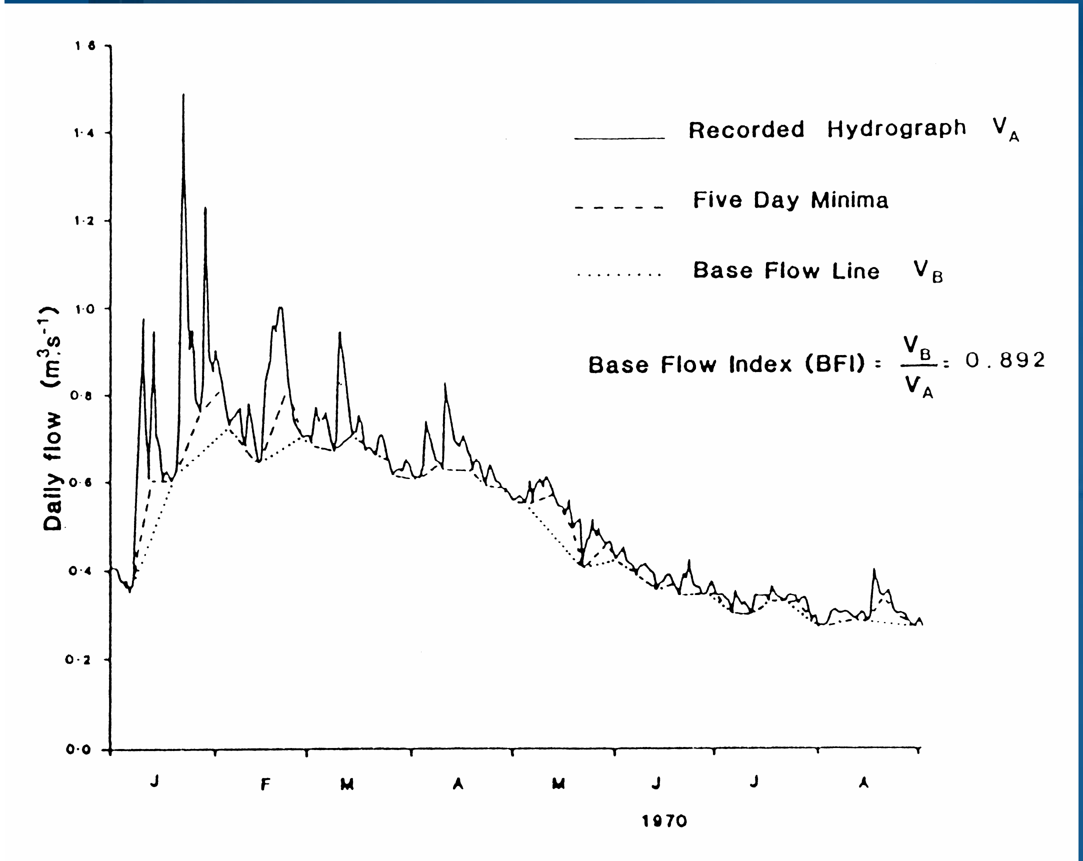
(Institute of Hydrology, 1980)

(2) Recursive digital filter

(Lynn, P. A., 1973)

# (1) Smoothed minima technique :

## (Institute of Hydrology, 1980)




(a) Divide the data into **non-overlapping blocks** time interval and calculate the minima for each of these blocks.

(b) If **0.9*central value < outer values**, then the central value is an ordinate for the slowflow line, these points are called **turning points**.

(c) Connecting turning points to get the slowflow line.

## (2) Recursive digital filter :

**(Lynn, P. A., 1973)**

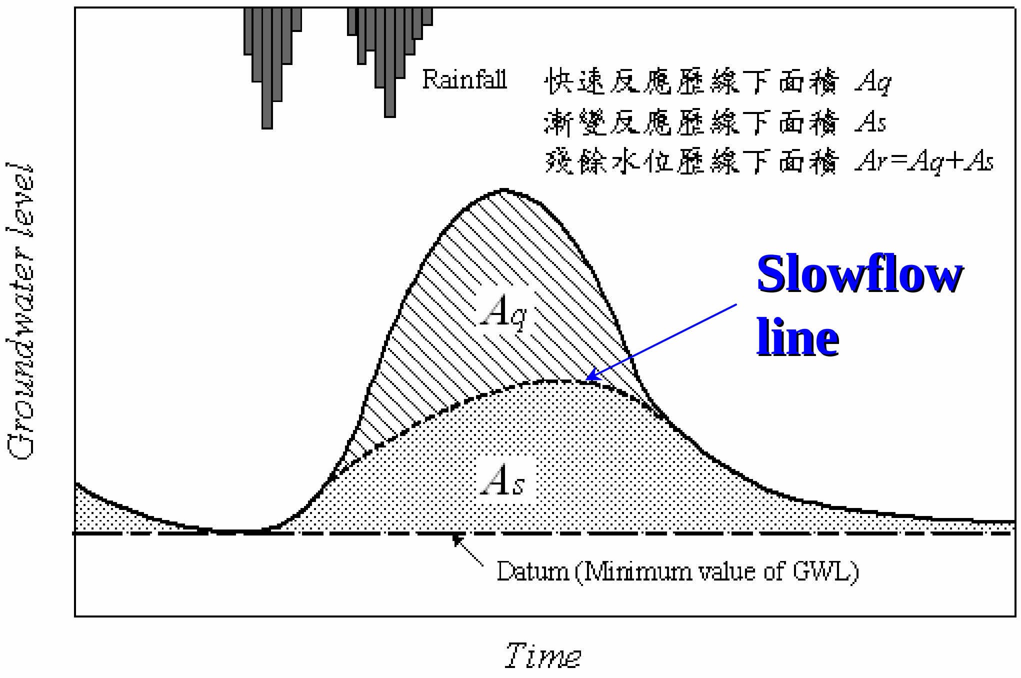
$$F_i = \lambda F_{i-1} + \frac{1+\lambda}{2}\left(H_i - H_{i-1}\right)$$

$F_i$ **is the filtered quick response at the ith sampling instant,**

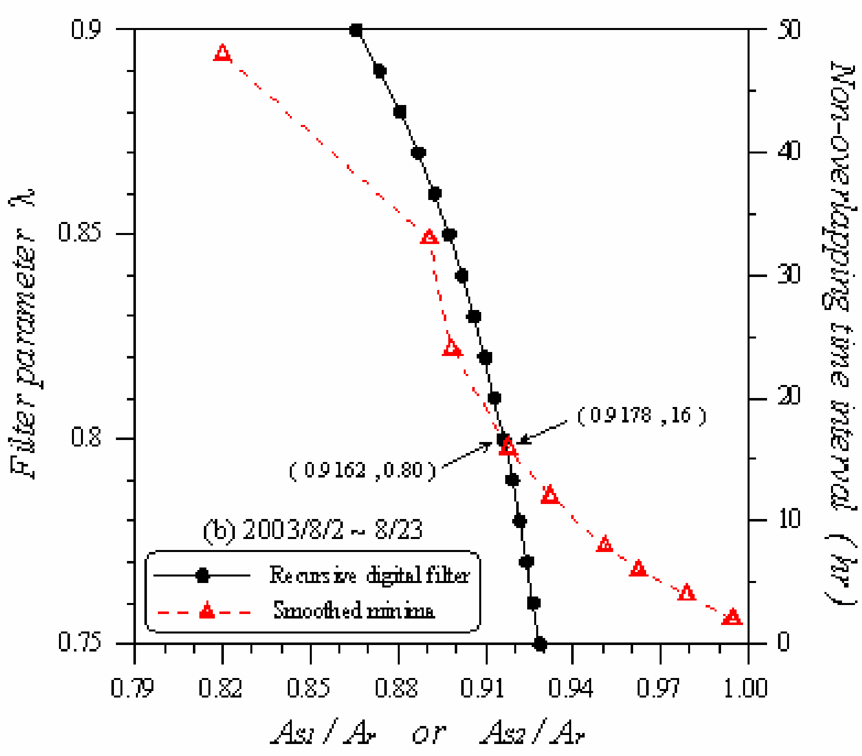
$H_i$ **is the original residual groundwater level,**

$\lambda$ **is the filter parameter.**

# Quick / Slow response separation :

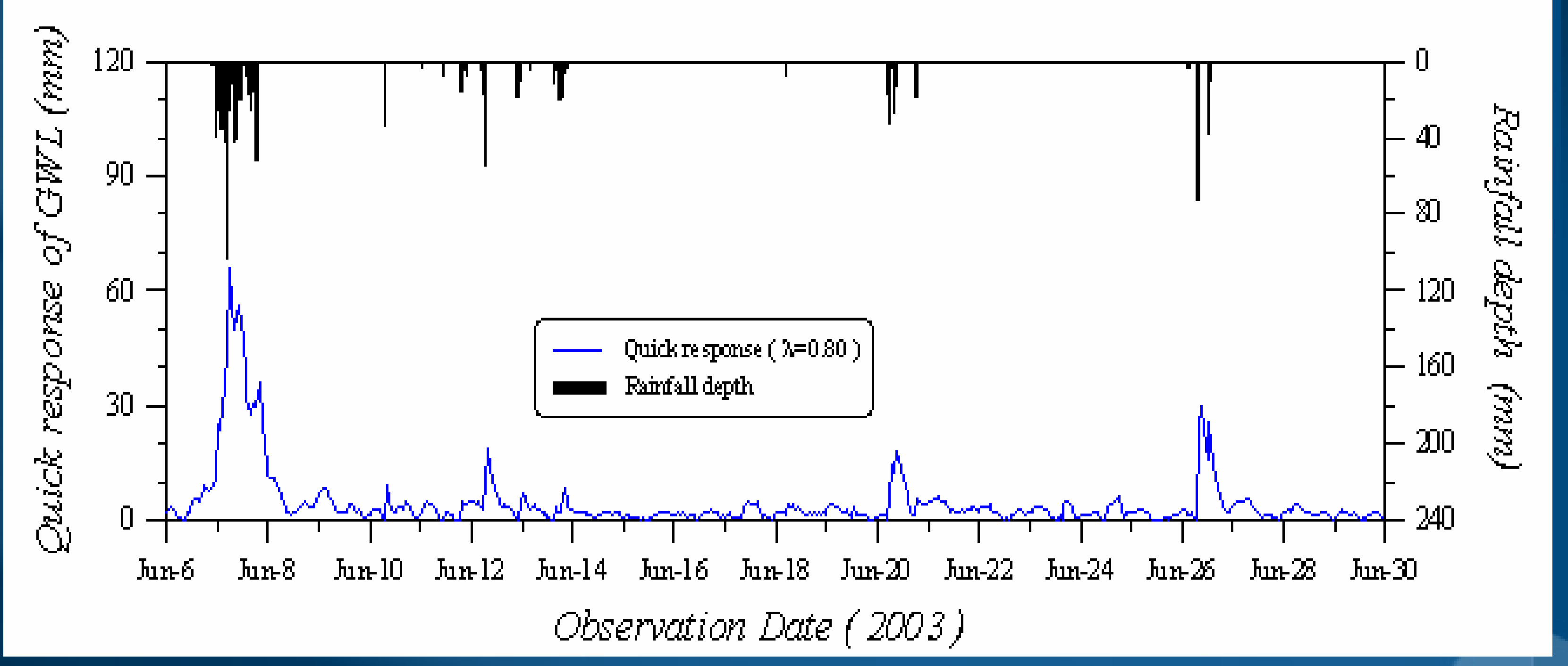



$$Ratio = \frac{A_s}{A_r} = \frac{A_s}{A_q + A_s}$$



## ➢ Quick rainfall response :

The result shows that the recursive digital filter method with a filter parameter of 0.8 was suitable to separate the quick and slow responses from groundwater level at Naba well station.




Comparison of the series of rainfall depth and its corresponding series of quick response on groundwater level.

- **Unit rainfall function** for rainfall-induced groundwater level increment：

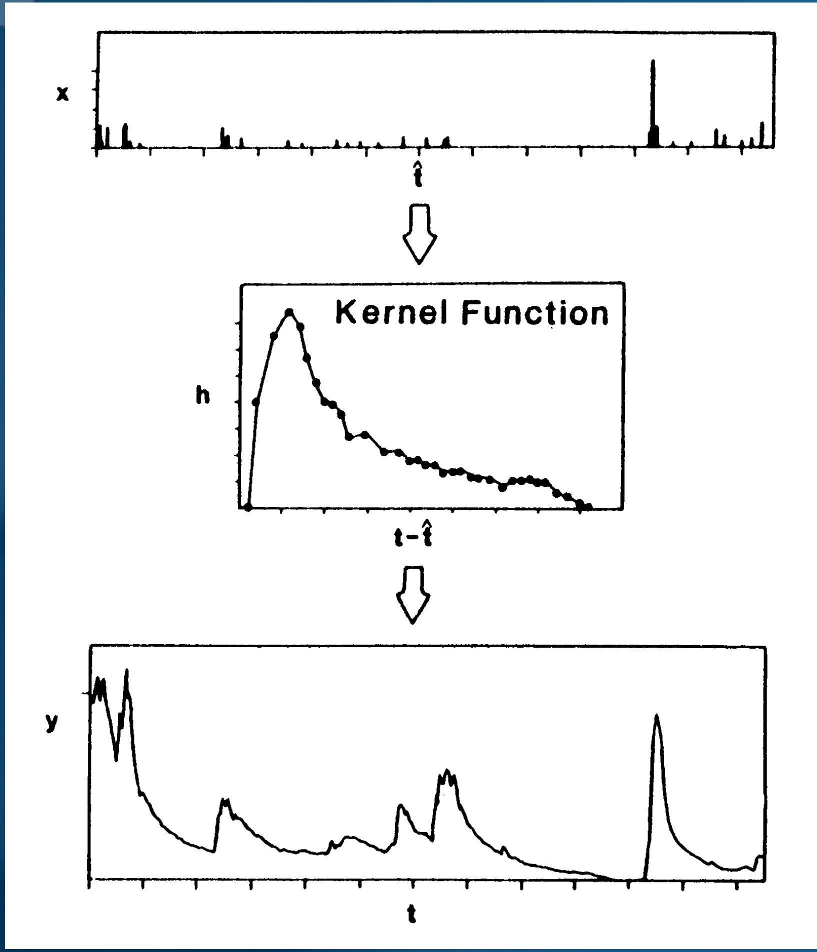
$$y(t) = \int_0^t h(t-\tau)\, x(\tau)\, d\tau$$

Quick response of residual GWL

Kernel function (unit rainfall response)

Rainfall depth

# Linear system analysis :

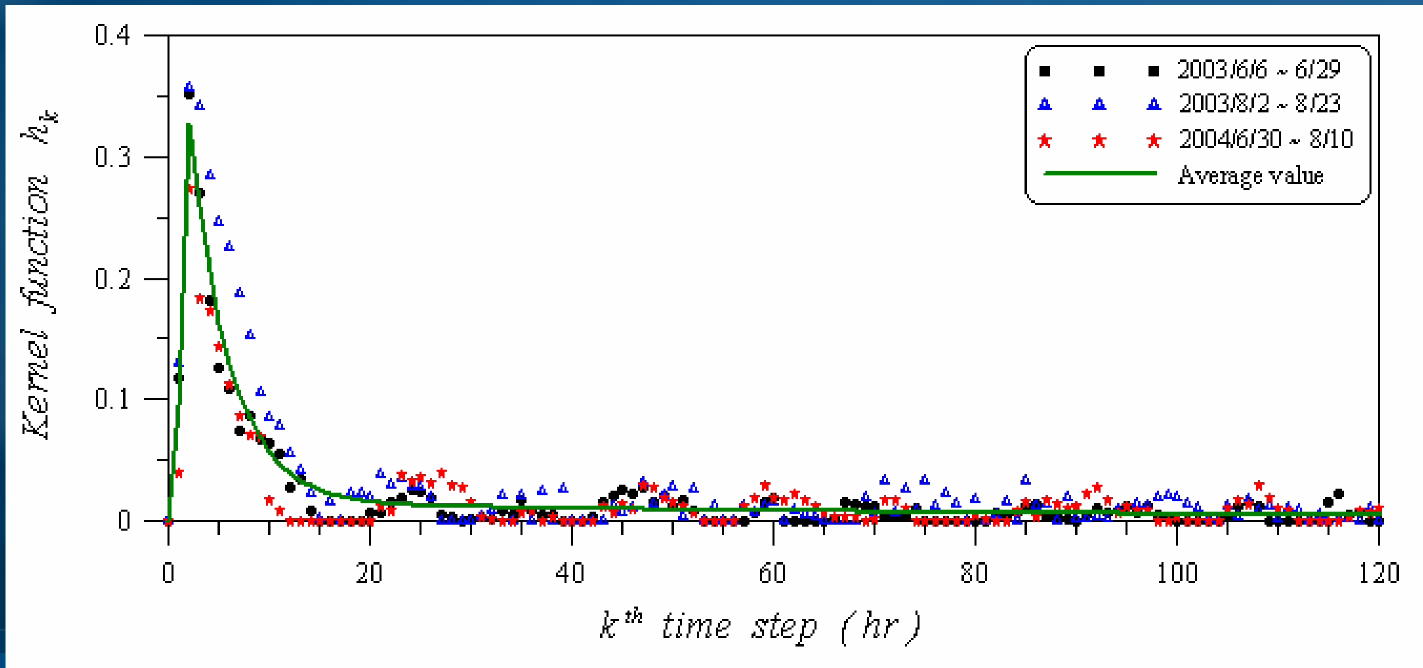



- This study takes the unit rainfall depth as an input time series and the quick rainfall response as an output series, and then to find the unit response function for the quick rainfall response on groundwater level via a linear system analysis.

Quick rainfall response + rainfall depth ----> Kernel function

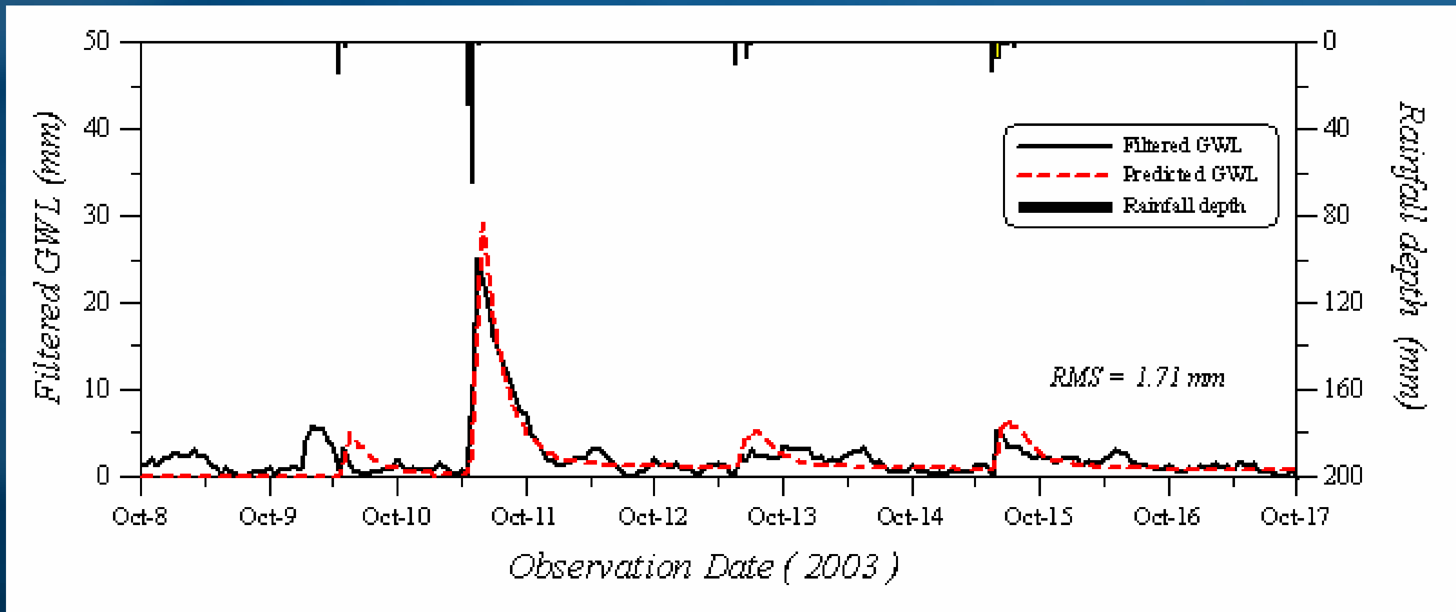
- The unit response function **sharply rise and up to a peak after about 2 hours**, and then **exponentially drop** to some small value.

- An **average unit response function** (Kernel function) of rainfall on groundwater level that was obtained via a linear system analysis, basing on the data of rainfall and groundwater levels during three periods.



## ➢ Simulated groundwater level variation:

**The unit response function could be used to estimate the rainfall quick response on groundwater level once the rainfall data is given.**



# *Conclusion:*

1. Rainfall effect on the groundwater level could be divided into two parts: quick response and slow response. The quick rainfall response may remain few minutes to few hours, while the slow rainfall response may last few days or weeks.

2. The base-flow separation methods, such as the smoothed minima technique and recursive digital filter method, were used to separate the quick and slow rainfall responses from groundwater level.

# Conclusion:

3. The recursive digital filter method with a filter parameter of 0.8 was suitable to separate the quick and slow responses from groundwater level at Naba well station.

4. This study takes the unit rainfall depth as an input time series and the quick rainfall response as an output series, and then to find the unit response function for the quick rainfall response on groundwater level via a linear system analysis.

## Conclusion:

5. The unit response function sharply rise and up to a peak after about 2 hours, and then exponentially drop to some small value. The unit response function could be used to estimate the rainfall quick response on groundwater level once the rainfall data is given.

***Thanks for your attention !!***

4th Taiwan-Japan Joint Workshop on Hydrological Research for Earthquake Prediction

# *Rainfall-induced groundwater level variation*

## *--- Unit Rainfall response*

**Chyan-Deng Jan and Tsung-Hsien Chen**

**Department of Hydraulic and Ocean Engineering**
**National Cheng Kung University**