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Field Monitoring in the Yilan River Experimental Watershed

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ABSTRACT

Numerical models play an important role in disaster warning system, especially flood warning system in Taiwan. Warning information based on simulations can lead better decision making of disaster prevention and mitigation before flood. Monitoring data in field are essential for calibrations and validations of numerical model. However, monitoring data are often insufficient for watersheds in Taiwan. To increase monitoring data and improve accuracy of simulations, this study, therefore, established experimental watershed in the Yilan River basin since 2012. In the Yilan River Experimental Watershed, totally 66 sites were installed including rainfall, river water level, river surface velocity and inundation water level. Measurements of river surface velocity and inundation water level are unique in the world. River surface velocity data are applied to estimate discharge history during flood using index velocity method and inundation water level are monitored continuously to improve current manual work. All monitoring data in the Yilan River Experimental Watershed can be downloaded on the website http://wraew.ttfri.narl.org.tw/.

KEY WORDS: Experimental Watershed; Yilan River; Discharge; Inundation.

INTRODUCTION

Flood prediction and disaster warning system in Taiwan was built based on simulations. Numerical models therefore play an important role in disaster warning system. Warning information based on simulations can make better decision for disaster prevention and mitigation. To match field condition, calibrations and validations based on field monitoring data are essential before applications. Area of Taiwan is 36,000 km^2 and there are 745 rain gauges (Central Weather Bureau 2014, Water Resource Agency 2015) and 141 water level sites (Water Resource Agency 2015). However, site distributions for rainfall and river water level are non-uniform and insufficient in some watersheds. Rain gauges with non-uniform distribution will lead to bias runoff simulations, especially in mountain area. Similarly, insufficient river water level sites easily lead unreasonable parameters after calibrations and validations of river routing simulation.

For runoff and river routing simulations, discharge is used as validations and upstream boundary conditions. Head-discharge rating curve is officially used to estimate discharge in Taiwan (Hsu *et al.* 2006). Head-discharge rating curve is basically built based on measurement. However, discharge measurements in field are difficult during typhoon and flood. Short discharge data during flood will extremely lead wrong head-discharge rating curve which estimates wrong discharge for upstream boundary condition of river routing simulations.

High intensity rainfalls, especially in typhoon, often cause inundation in Taiwan. Currently, inundation situations are investigated and recorded manually in Taiwan. These records are not continuous and cannot provide complete history of inundation, such as flooding depth variations and inundation durations. In general, only maximum inundation area or maximum flooding depth is considered for model calibration and validations (National Taiwan University 2015). However, inundation history is continuous and dynamic. Reliability of used inundation model describing inundation history is therefore low. To enhance reliability of inundation simulations and present more details, more inundation sites and continuous monitoring method are necessary.

To increase monitoring data for simulations, this study establishes experimental watershed (Renard *et al.* 2008) in the Yilan River basin since 2012. More monitoring sites of rainfall, river water level, river surface velocity and inundation water depth are considered. In addition, to get complete discharge and inundation history during typhoon and flood, discharge measurement by acoustic Doppler current profiler (ADCP), discharge estimation using index velocity method and continuous inundation monitoring are introduced in this study.

YILAN RIVER EXPERIMENTAL WATERSHED

The Yilan River Experimental Watershed locates at northeastern side of Taiwan, shown as Fig. 1. The watershed area is 149.06 km^2 including urban area (12 %), agricultural area (68 %) and mountain area (20 %). The river length is 17.25 km. Levees were built and occupy 49.64 % of river length. Several irrigation and drainage system are found in the watershed. The Meifu drainage system locating in southern side of the Yilan River is the major drainage system. The watershed of the Meifu drainage system is an area with high inundation potential. Fig. 2a shows rivers and terrain in the Yilan River basin.

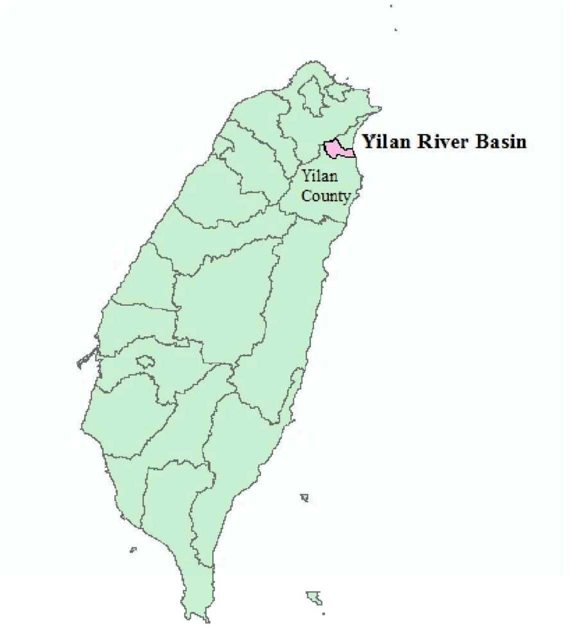

Fig. 1 Position of the Yilan River Experimental Watershed

SITES AND SENSORS

Fig. 2a shows the sites in the Yilan River Experimental Watershed before 2012. There were 5 sites for rainfall, 2 sites for river water level and 5 sites for inundation water level. The site amount is 66 from 12 after considering characteristics of the Yilan River Experimental Watershed and needs of simulations. New sites of rainfall are considered inter-zone of mountain and plain area. New sites of river water level are considered increasing validation data in main reach and tributaries. Sited of river surface velocity are installed at the upstream reaches for discharge estimation as validations for runoff simulations and upstream boundary condition for river routing simulations. All sites of inundation water level are considered in areas with high inundation potential. Fig. 2b shows sites in the Yilan River Experimental Watershed now, including 11 rain gauges, 14 river water level sites, 5 river surface velocity sites and 36 inundation water level sites. The ownership of sites includes Central Weather Bureau, Water Resource Agency, Yilan County Government and Taiwan Typhoon and Flood Research Institute.

Sites of river surface velocity are installed to estimate discharge during flood. Two sites locate at two tributaries to provide upstream boundary of river routing simulations and discharge validation of runoff simulations. One site is installed after tributaries converging to check discharge for river routing simulations.

All 36 sites of inundation water level are installed in areas with high inundation potential and 31 sites among all sites locates in Meifu drainage basin. Installed sensors record continuous inundation water level and these data are then used for calibrations and validations of inundation models to match rapidly change inundation characteristic in Taiwan. Inundation monitoring in the Ylan River Experimental Watershed is essential in Taiwan and unique in the world.

The sensors used for rainfall, river water level, river surface velocity and inundation water level are tipping bucket gauge (TK-1, Japan), radar sensor (VEGAPULS61, Germany), continuous wave radar (RG-30, Austria) and pressure-type water level sensor (PM420W, Taiwan), respectively. All sensors monitor and record data automatically and measurement interval is 1 min, except inundation water level sensors.

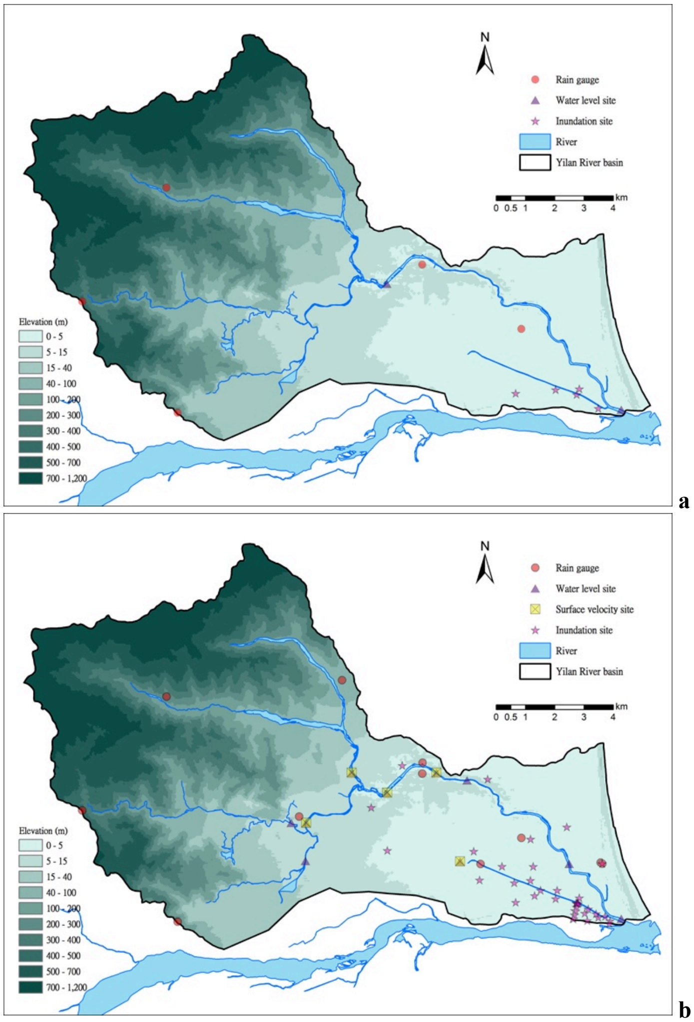

Fig. 2 Monitoring sites in the Yilan River Experimental Watershed: **a** before 2012; **b** after 2012

MONITORING DATA AND SHARE

Monitoring data in the Yilan River Experimental Watershed starts since 2012/7. To facilitate usage for researches, monitoring data are organized monthly. In addition, for studies on floods, monitoring data during typhoon and flood events are also organized. Totally 21 events, including typhoons and heavy rains, are collected, shown in Table 1. To facilitate analysis and simulations, users can download monitoring monthly and event data via website http://wraew.ttfri.narl.org.tw/. The website also presents real-time monitoring data in the Yilan River Experimental Watershed.

Table 1 Organized typhoon and flood events for data share

Year/month	Event/Typhoon name	Typhoon number	Period of data
2012/7	Saola	201209	7/29-8/4
2012/8	0807HR	---	8/6-8/9
2012/8	KaiTak	201213	8/12-8/16
2012/8	Tembin	201214	8/21-8/25
2012/9	Jelawat	201217	9/26-9/29
2013/7	Soulik	201307	7/10-7/14
2013/7	Cimaron	201308	7/16-7/19
2013/8	Trami	201312	8/19-8/23
2013/8	Kong-Rey	201315	8/26-9/1
2013/9	Usagi	201319	9/18-9/23
2013/10	Fitow	201323	10/3-10/8
2014/7	Matmo	201410	7/20-7/24
2014/8	0809HR	----	8/6-8/14
2014/9	Fung-Wong	201416	9/18-9/26
2015/5	Noul	201506	5/9-5/12
2015/5	Meiyu	---	5/21-5/27
2015/7	Linfa	201510	7/6-7/9
2015/7	Chan-Hom	201509	7/9-7/11
2015/8	Soudelor	201513	8/7-8/9
2015/8	Goni	201515	8/22-8/23
2015/9	Dujuan	201521	9/27-9/30

DISCHARGE MEASUREMENT AND ESTIMATION

The major method of discharge estimation in Taiwan is head-discharge rating curve built based on measured discharge. However, measurement data in field at high discharge during flood are short which highly influence correctness of head-discharge rating curve and then estimate wrong discharge data, especially at high discharge. The mistake extremely decreases reliability of runoff and river routing simulations and disaster warning system. To improve quality of discharge data, this study considers discharge measurement using acoustic Doppler current profiler (ADCP) in flood (Atsuhiro *et al.* 2012) and index velocity method (Leveaque & Oberg 2012) to estimate discharge during flood. The arrangement of ADCP, water level sensor and radar sensor for river water surface velocity measurement at a site for discharge measurements and estimations is shown in Fig. 3.

The proposed procedure of discharge estimation is shown in Fig. 4. Water level, H, is detected and area of flow, A, is then calculated according river cross section. Observed discharge, Q_{adcp}, is measured by ADCP and observed mean velocity, U_{adcp}, is calculated. The continuous surface velocity, u_s, is detected by radar sensor. The ratio of mean velocity and surface velocity, α, can be calculated from U_{adcp} divided by corresponding u_s at the same time. Mean ratio is used for following discharge estimations and u_s is transferred to mean velocity, U, by multiplying mean ratio α. The complete discharge history, Q, is then calculated by U multiplying A.

Fig. 5 shows the comparisons between measured and estimated discharges at the Yuanshan Bridge during typhoon Soudelor (2015/8). This result presents that discharges estimated by proposed method matching measurements by ADCP, that is, proposed method is reliable during flood.

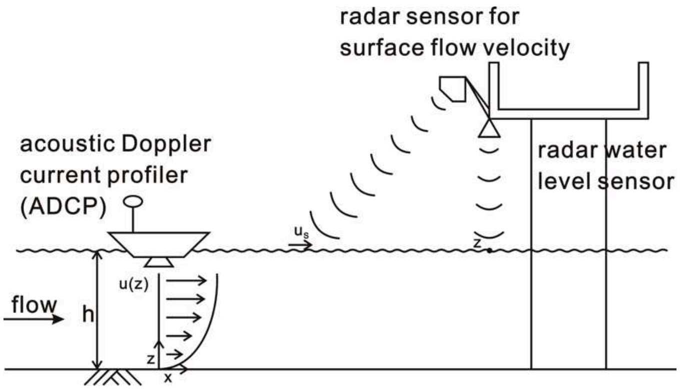

Fig. 3 Sensor and instrument arrangements for discharge measurements

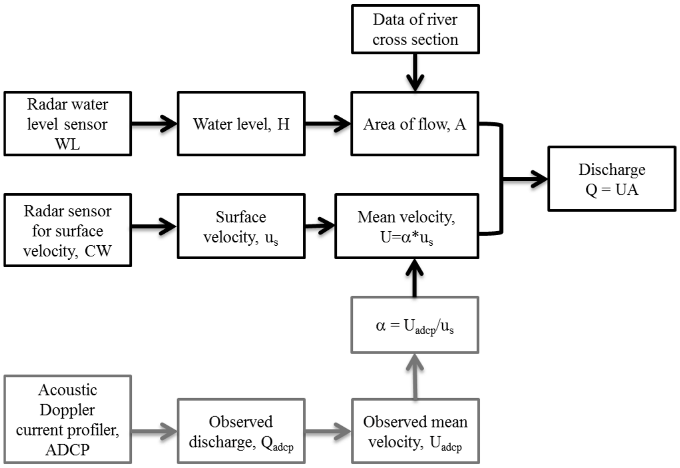

Fig. 4 Procedures of discharge estimation

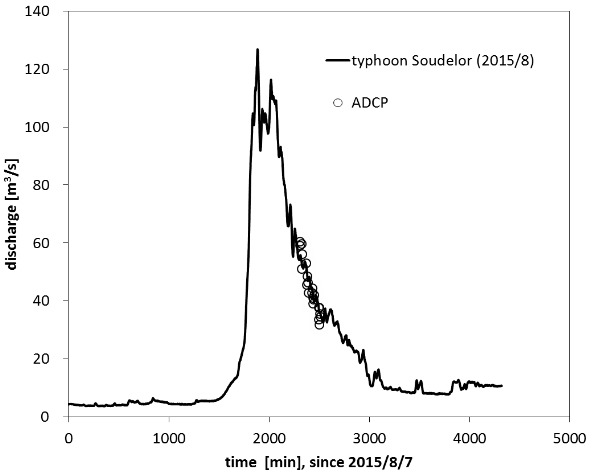

Fig. 5 Comparisons between measured and estimated discharge at the Yuanshan Bridge during typhoon Soudelor.

INUNDATION MONITORING

Staff gauge is commonly used to identify and record inundation water depth manually, shown as Fig. 6. This method is hard to provide continuous data for inundation analysis and simulations. To improve data quality, pressure-type water level sensors with data logger are therefore installed, as shown in Fig. 7. The sensor records water level of inundation continuously.

Fig. 8 shows variations of flooding depth at 7 sites in the Meifu Drainage basin during typhoon Saola (2012/7). The starting time of inundation, the highest flooding depth and inundation duration are easily identified from continuous monitoring data. The temporal and spatial transportation of inundation can be analyzed as well. In general, maximum inundation area and maximum flooding depth based on current rough investigations are used for calibrations and validations of inundation models. These data provide only extreme condition. Phenomena of inundation are dynamic and monitoring continuous inundation data is therefore crucial. In this study, data monitored by pressure-type water level sensors with data logger can be applied to inundation simulations and highly increase reliability of inundation models. Validated model can furthermore describe more details of inundation.

Fig. 6 Staff gauge for flooding depth measurement

Fig. 7 Pressure-type senor for flooding depth measurement

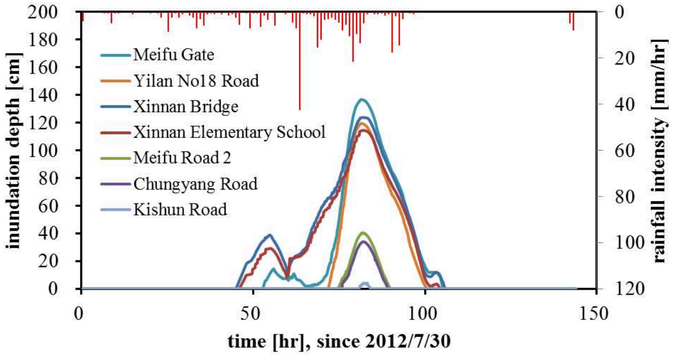

Fig. 8 History of flooding depth in the Meifu Drainage basin during typhoon Saola (2012/7)

CONCLUSIONS

A brief summary of this study is listed as following.

1. To enhance monitoring data quality and satisfy needs of simulations, the Yilan River Experimental Watershed has been established since 2012. Totally 66 sites have been installed, including rainfall, river water level, river surface velocity and inundation water level. Users can download monitoring data from http://wraew.ttfri.narl.org.tw/.
2. Acoustic Doppler current profiler is used to measure river discharge during typhoon and flood. Index velocity method is applied to discharge estimation during flood. The proposed methods highly improve the shortage of head-discharge rating curve and enhance reliability of discharge estimation.
3. Sites of inundation water level are installed in area with high inundation potential of the Yilan River Experimental Watershed. Pressure-type sensors with continuously recording function provide complete inundation history which highly promotes reliability of inundation models after calibrations and validations.

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