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Errors in Recorded Information and Calibration of a Catchment Modelling System(I)

- Analysis of Measurement Errors in Recorded Information -

기록치 오차와 유역모형의 검정(I)

- 기록치 내의 측정 오차 분석 -

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Abstract

A catchment modelling system is the summation of the numerous hydrologic, hydraulic and other process models necessary to simulate the response of a catchment to a storm event. Differences between the recorded catchment response and that predicted by a catchment modelling system can arise from structural errors within the catchment modelling system, evaluation errors in the control parameters, or measurement errors in the recorded data being used to assess the reliability of the evaluation of the control parameters. Presented herein is an investigation of the potential measurement errors within the recorded information, which was considered to occur from instrument error in the ultra sonic flow monitor. This investigation was undertaken using three available rating curves at the Musgrave Avenue Stormwater System in Centennial Park, Sydney, developed by Abustan (1997), Water Board (1994), and using Manning's equation.

Keywords : Measurement error, Recorded information, Flow measurement, Rating curve

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I. Introduction

Effective catchment management is a complex task that, over the past decades, has increased in importance to the general community. It has become increasingly important, therefore, that managers of catchments obtain information regarding the catchment response to various combinations of existing and proposed catchment conditions under a variety of hydrologic conditions. Since the development of the digital computer and its current widespread availability, this information more commonly is being obtained from implementation of catchment modelling

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systems. Implementation of a catchment modelling system requires three steps, which are the calibration of the system, the validation of the calibration, and the extrapolation of the system to the various combinations of catchment and hydrologic conditions. The robustness of the simulations when this extrapolation is undertaken is related to the calibration and validation of the catchment modelling system, and the data used to evaluate the many control parameters influencing the predicted response of a catchment.

A catchment modelling system for simulation of both the quantity and quality of stormwater runoff can be considered to consist of four conceptual components, which are *Generation, Collection, Transport, and Disposal* (Ball, 1992). Within each of these components, there are many alternative transformations available with each of these transformations being the result of different combinations of process models. There are numerous combinations of transformation and information from a preceding component that map to a single output. The concept of system calibration, therefore, is to select the appropriate transformations and information for the catchment being simulated. Since the transformations or process models are defined once the catchment modelling system has been selected, calibration usually consists of determining the values of the control parameters (input data) for each of the conceptual components so that the resultant system of process models and input information mimics the real response of the catchment.

Since surface runoff varies with the catchment characteristics, calibration of a catchment modelling system usually requires adjustment of the model control parameters to minimise prediction errors which are defined as the error between the monitored data and the predicted data from the catchment modelling system. Following calibration of the control parameters, validation of the determined values is undertaken to assess the robustness of the control parameters using independent sets of data to those used during the calibration process.

An inherent assumption in this process, usually, is that there is no errors in the recorded information and that any errors do not impact on the error minimisation. In other words, calibration and validation of a catchment modelling system requires accurate information with sufficient temporal and spatial definition to enable evaluation of control parameters. In practice, however, the available data from most catchments is not error free and it is unknown how errors propagate through many catchment modelling systems.

Because of this reason, much attention has been placed on the influence of calibration data on the estimation of model control parameter values. According to Gan et al. (1997), calibrated control parameter values are data dependent because calibration uses recorded values for adjustment of the parameters by comparison with simulated values, and, hence, recorded data is one of major factors affecting the attainment of an optimum parameter set. Ibbitt (1972) examined the effect of random data errors on the accuracy of the parameter estimates. The values of fitting criterion were found to depend largely on the errors in the runoff record. Troutman (1985) noted that calibration in the presence of input error (or model error) may result in questionable estimation of model parameter values. Sorooshian et al. (1993) and Gan et al. (1996) also mentioned that data measurement errors are one of the difficulties for achieving an actual optimum parameter set.

In fact, many errors and uncertainties may appear during rainfall-runoff transformation, such as measuring and discretisation errors of rainfall and runoff, synchronisation errors of rainfall and runoff, uncertainties in the rainfall areal distribution (spatial variation), uncertainties in the temporal variation of rainfall, uncertainties in loss function, and measuring errors in catchment characteristics, etc (Desbordes, 1981). These errors provide wrong information for simulation of rainfall-runoff processes through a catchment modelling system. The knowledge of magnitude of possible measurement errors is, therefore, important to prevent biased interpretation of the analysis.

Associated with this situation, an investigation into the possible measurement errors of recorded information was undertaken. Presented in this paper are a brief review of alternative forms of errors within recorded information and the results of this investigation.

Ⅱ. Error Analysis

1. Errors in Recorded Information

Recorded data errors may occur in any measurement sequence. Design of measurement protocols is aimed at minimising the development of these errors. In general, errors that occur during a measurement can be classified as

- *Mistakes* : These are due to inexperience or carelessness on the part of the person taking the measurement. Consequently, these errors are quite random in occurrence and magnitude. If allowed to pass unchecked, faulty information will result. By careful planning, however, suitable check measurements can be obtained and mistakes corrected prior to insertion into the catchment modelling system as input data.
- *Systematic or cumulative errors* : These errors arise from sources which are known and, consequently, their effects can be eliminated. An example of a systematic error is the drift in an instrument measuring the depth of water in a river. By noting the water surface level during a station visitation, the drift in the instrument continuously recording the water depth can be determined and then corrected during the editing phase of the information cycle.
- *Random error* : This third group of errors arise from the lack of human perfection. They are not mistakes and there is as much chance of them being positive as being negative. In addition, these errors tend to be self-compensating as they tend to cancel each other. Usually, these errors are smaller in magnitude to the systematic errors and mistake errors. Usually, no attempt is made to correct for these errors.

While it may not be possible to remove all sources of error from the analysis, it is important to aware of them to interpret data obtained the modelling system accordingly.

When it is necessary to evaluate control parameters for application of a catchment modelling system, there may, or may not, be sufficient gauged information available to enable the desired evaluation. Only the situation where gauged data are available is considered herein.

2. Gauged Information

The School of Civil and Environmental Engineering at the University of New South Wales (UNSW) installed in 1993 two 0.2 mm tipping bucket pluviometers at Waverley Public School and at Musgrave Avenue Stormwater Channel (SWC) in Sydeny for measuring rainfall. The recorded rainfall data was down loaded fortnightly into HYDSYS, a computer system used to store, process, analyse and report hydrometric time series. At the gauging station installed on Musgrave Avenue Stormwater Channel, flow quantities were recorded continuously by an ultrasonic probe which recorded the flow depth. The rainfall and flow information were, therefore, available from HYDSYS with a variety of time steps.

Table 1 shows information of the monitoring stations within the catchment. For this study, flow records were extracted from HYDSYS in the form of instantaneous value at the end of a time interval, and the time step of these values was 5 minutes.

Table 1 Monitoring stations

Station No.	Station name	Type	Period	Operation authority
566010	Waverley Public School	Rainfall gauge (RDL data logger)	10/97 to present	UNSW
2132238	Musgrave Avenue Channel	Rainfall gauge (HM2000 data logger)	12/96 to present	UNSW
2132238	Musgrave Avenue Channel	Water level gauge (HM2000 data logger)	06/94 to present	UNSW

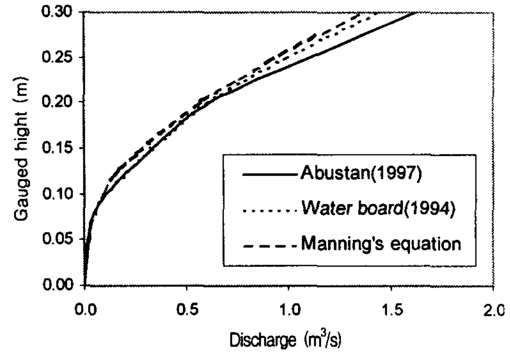

Fig. 1 Three available rating curves at Musgrave Ave. SWC

3. Available Rating Curve

There are three available rating curve informations at the Musgrave Avenue Channel (Station no. 2132238). These rating curves were established by Abustan (1997) derived from physical model and field gaugings, by Water Board (1994), and using Manning's equation. A comparison of these three rating curves is shown in Fig. 1.

Among the three rating curves, the Abustan rating curve found to be more reliable due to the known data used in its development, but all three available rating curves were used to identify influences of the selection of different rating curves on the range of possible measurement error bounds of the discharge information.

4. Analysis of Measurement Error

In order to define accuracy of recorded information, the potential measurement error was evaluated in this study. Error in the recorded information was considered to occur from instrument error in the ultra sonic flow monitor.

The accuracy of the stage measurement is 0.25 % of the total range of the instrument, and the resolution of the instrument is 3 mm. The range of measurement of this instrument is 0.25 to 5 m. These can be converted to the accuracy of the flow measurement. The potential measurement error therefore can be calculated as Equation (1).

$$E(mm) = \pm S \times A \pm R \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \ (1)$$

Where E : Potential Measurement error
S : Range of the instrument
A : Accuracy of the stage measurement (ie. 0.25%)
R : Resolution of the instrument (ie. 3 mm)

The accuracy of a flow rate for a given stage can be obtained after adding or subtracting the water level measurement error accuracy from a stage point (ie. a measured point value) using Equation (1). The range of uncertainty in the flow information therefore can be found between these lower and upper bounds. In other words, the true value of the data point can be assumed to be located within these ranges.

Evaluation of the control parameter values requires the simulated values be within the range of values associated with the recorded information. An exact duplication of the recorded data by the simulated values requires either perfect data or a relationship between the recorded data and the control parameter values.

Ⅲ. Results and Discussions

Presented in Table 2 are the values of runoff volume and peak flow derived from the three rating curves, while Table 3 shows the potential measurement error calculated using Equation (1), for the runoff volume and peak flow values shown in Table 2. In these tables, A, W and M stand for Abustan, Water Board and Manning's equation rating curves respectively. The positive sign shown in Table 3 presents upper bound of measurement error for the recorded values, while the negative means lower bound of it.

As shown in Table 3, each event had different magnitude of potential measurement error, and the range of error bounds found to be increased in proportion to the rainfall intensity, while the duration of rainfall seemed not likely to affect the size of the errors. The degree of the magnitude of measurement error however could be different depending on the rating curve selected. The reason of this is that each rating curve has different determination of the flow rate against the same water level. Consequently, different

Table 2 Runoff volume and peak flow derived from each rating curve

Events	Runoff volume (m^3)			Peak flow (m^3/s)		
	A	W	M	A	W	M
94.11.04	1,886.1	1,774.2	1,688.1	0.849	0.793	0.796
94.11.29	1,203.6	1,167.6	1,031.7	0.382	0.395	0.356
95.01.28	3,074.7	2,857.8	2,704.2	0.896	0.832	0.808

Table 3 Potential measurement error for the runoff volume and peak flow

Events	Runoff volume (m^3)			Peak flow (m^3/s)		
	A	W	M	A	W	M
94.11.04	±99.3	±92.1	±93.3	±0.033	±0.028	±0.028
94.11.29	±77.4	±82.5	±80.4	±0.019	±0.017	±0.018
95.01.28	±177.0	±158.7	±155.1	±0.049	±0.027	±0.028

amount of flow rate has different magnitude of error. It was also noted that proportional measurement error for runoff volume and peak flow were different for the same event. The calculated possible potential errors in runoff volume for the first event (94.11.04) ranges from 5.2% to 5.5%, while 3.5% ~ 3.9% were obtained for peak flow. From the results of the second and third events (94.11.29 and 95.01.28), the possible error range for runoff volume was shown to be 6.4% ~ 7.8% for the second event and 5.6% ~ 5.8% for the third event, while for peak flow, the error range 4.3% ~ 5.1% and 3.2% ~ 5.5% were obtained from the second and third events respectively.

Shown in Table 4 and 5 are the possible upper and lower values of the runoff volume and peak flow. As can be seen in these tables, the possible range of the runoff volume was observed to be between 1,594.8 m^3 and 1,985.4 m^3 for the first event, while for the second and third events, the range was 951.3 m^3 ~ 1,281.0 m^3, and 2,549.1 m^3 ~ 3,251.7 m^3 respectively. For the case of peak flow, the possible value could be located within 0.741 m^3/s ~ 0.882 m^3/s, 0.338 m^3/s ~ 0.412 m^3/s, and 0.780 m^3/s ~ 0.945 m^3/s for the three events respectively. From these results, it was found that, in most cases, the bigger possible error values for both runoff volume and peak flow were obtained when the Abustan rating curve was used, and the smaller possible error values were achieved from the use of Manning's rating curve. These results were caused from the reason mentioned earlier in this section. In addition, selection of a rating curve also can be one of possible error sources for flow information as the rating curve is another form of information, which also contains uncertainty in itself. It does not mean, however, that a rating curve generating bigger measurement error range imply to be less reliable, since the location of true value could be anywhere within the range. The wider range of error bounds however could make genetic evaluation of control parameters more difficult.

Table 4 Possible upper values of the runoff volume and peak flow

Events	Runoff volume (m^3)			Peak flow (m^3/s)		
	A	W	M	A	W	M
94.11.04	1,985.4	1,866.3	1,781.4	0.882	0.821	0.797
94.11.29	1,281.0	1,250.1	1,112.1	0.401	0.412	0.374
95.01.28	3,251.7	3,016.5	2,859.3	0.945	0.859	0.836

Table 5 Possible lower values of the runoff volume and peak flow

Events	Runoff volume (m^3)			Peak flow (m^3/s)		
	A	W	M	A	W	M
94.11.04	1,786.8	1,682.1	1594.8	0.816	0.765	0.741
94.11.29	1,126.2	1,085.1	951.3	0.363	0.378	0.338
95.01.28	2,897.7	2,699.1	2549.1	0.847	0.805	0.780

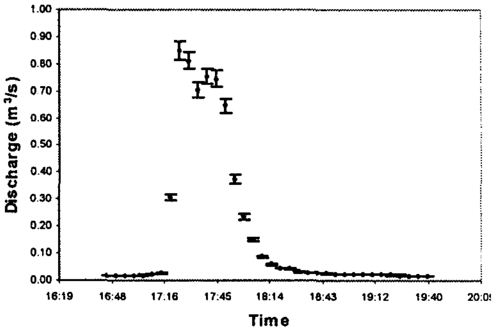

Fig. 2 Potential measurement error bounds for the event Nov. 4, 94

An example of the error bounds for each point flow of the event on Nov. 4, 94 is illustrated in

Fig. 2. As can be seen in this figure, the higher water level contains bigger error ranges comparing to lower water level, and this error range is the possible observed areas in which true hydrograph may be located.

Ⅳ. Conclusions

The measurement error arises due to no absolute precision in measurements. Physical quantities obtained from experimental observations always, therefore, have some errors. Analysis of the propagation of these errors through the transformation in the analysis tools is an important aspect of the resultant accuracy of the information produced from the analysis.

From the investigation of potential measurement error within the recorded flow information, high ranges of potential errors were observed with the results of 5.2% ~ 7.8% in the runoff volume, and 3.2% ~ 5.5% errors in the peak flow for the selected events. The actual results, therefore, cannot be improved beyond these errors; otherwise the calibration will end up curve fitting which may result in a reasonable fit within the calibration period but will provide unreliable prediction for different wet periods. In order to overcome the over-fitting problem, ie. curve-fitting of the control parameter values, an alternative calibration approach is needed. The further study for this issue is presented in the second paper (Choi, 2003).

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