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Effect of Rainfall Data Errors on the Optimized Values of Model Parameters

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Abstract
The rainfall input to a rainfall-runoff model was arbitrarily increased and decreased in order to determine the magnitude of corresponding changes in optimized values of the model parameters. The optimized capacities of moisture stores representing surface storage capacity of a catchment changed by average amounts of +24% and −20% as rainfall input was changed by +10% and −10%, respectively. Values of other parameters showed changes of similar magnitude, but there was no uniformity in the magnitude of induced changes from catchment to catchment. The results cast doubt on the validity of relating optimized values of model parameters to physical characteristics of catchments.

Introduction

Areal rainfall data used as input to rainfall-runoff models cannot be estimated with accuracy from the normal raingauge network over Australia. There are some instrumental errors in the measurement of point data and errors in making estimates of areal rainfall from the point measurements.

Tauman *et al.* (1980) compared the common Australian 203 mm rain gauge with the World Meteorological Organization reference pit gauge at four locations in Australia and two in Papua New Guinea. Daily rainfall totals in the Australian rain gauge averaged 7·8% higher than the reference pit gauge for small falls (0·1–1·0 mm) and averaged 2·3% lower for falls greater than 3·1 mm. The overall catch of the Australian gauge, using all falls at all six stations, was 2·0% less than the reference pit gauge. The catch of the Australian gauge was found to reduce with increase in wind speed by 1·5% for each metre per second increase in wind speed. Other factors affecting the measurement of point rainfall in rain gauges have been intensively investigated over many years (Spreen 1947; Kurtyka 1953; Hutchinson 1968; Rodda 1971; Boughton 1981).

The estimation of areal rainfall from point data introduces further errors. Hall and Barclay (1975) listed 15 techniques for estimating areal rainfall and concluded:

> "Areal rainfall estimates based on point observations should only be regarded as an index of the true mean rainfall over a catchment, and errors between 10 and 20% can be regarded as normal. Where strong wind effects or mountainous catchments are being considered, errors up to 60% can be experienced."

Consequently, rainfall data input to rainfall-runoff models is almost certain to contain errors. Where parameter values in the model are optimized to calibrate the model against observed runoff data, errors in the rainfall data are compensated for by errors in the parameter values giving spurious values for the parameters. It is not possible to determine the absolute magnitude of errors in the parameter values because the true values of rainfall input are not known.

This paper reports the results of a study of the relative changes in parameter values caused by deliberate changes in the rainfall input.

Study Area

Five catchments, forming part of the Lockyer Valley some 80 km west of Brisbane, in south-east Queensland (Fig. 1), were used in the study. Details of the catchments are given in Table 1. A detailed description of each catchment is given in Sefe (1981).

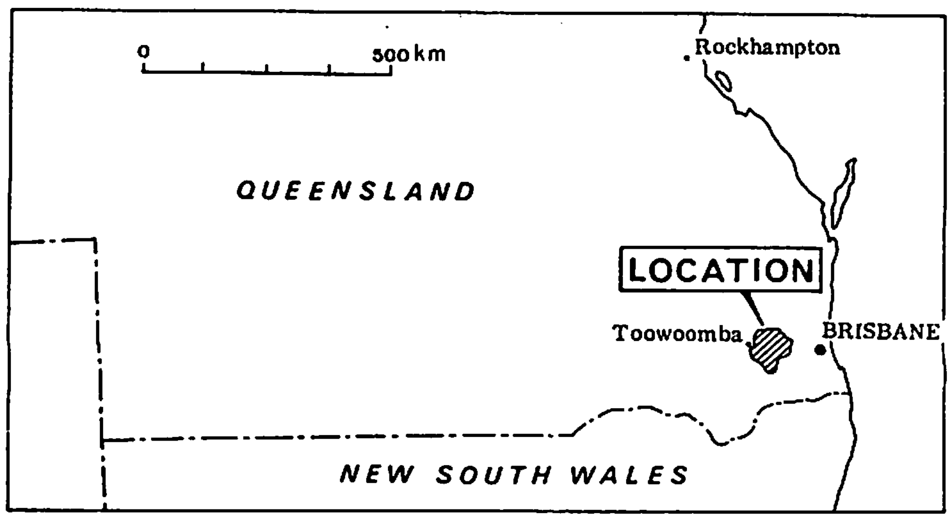

Fig. 1. Location of study area.

Table 1. Catchments used in the study

G. S. No.	Stream	Gauging station	Catchment area (km²)
143208	Fifteen-Mile Creek	Damsite	88
143209	Laidley Creek	Mulgowie	179
143211	Buaraba Creek	15·8 km	250
143212	Tenthill Creek	Hotel	455
143214	Flagstone Creek	Windolfs	150

The results of a study (Sefe 1981) of five different techniques for estimating areal rainfall from point rain gauge records showed that the Areal Reduction Factor (ARF) technique (Rodriguez-Iturbe and Meija 1973) gave least errors for the catchment sizes and location of the study area. The ARF technique was therefore used to give a best estimate of the true areal rainfall for input to the rainfall-runoff model.

The model used in the study is a version of the Boughton model (Boughton and Simpson 1978; Boughton 1981). The model structure is shown in Fig. 2, and the model parameters are listed in Table 1. The model uses daily rainfall data and estimates of daily evapotranspiration to calculate daily volumes of runoff. The parameters listed in Table 2 were optimized using the steepest descent procedure, as modified by Johnson and Pilgrim (1973), to minimize the sum of squares of differences between monthly totals of estimated and observed runoff.

First, the model parameters were optimized using the estimate of the true areal rainfall. All daily values of the areal rainfall were then increased by 10%, and the parameter values in the model were again optimized. Finally, the daily values of

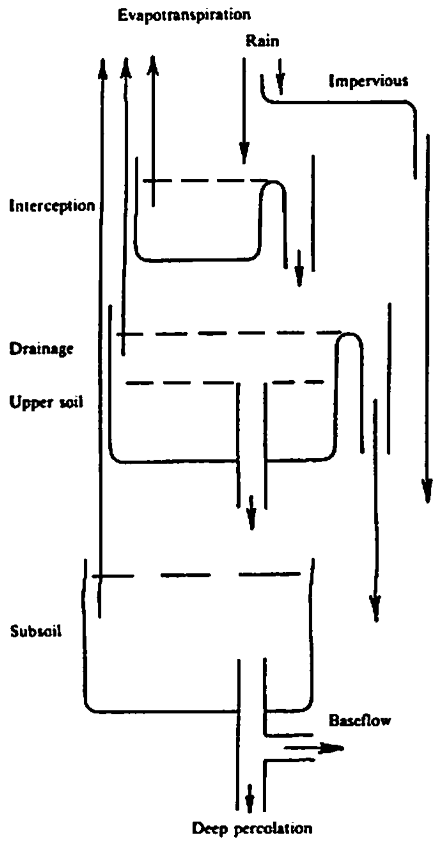

Fig. 2. Structure of the rainfall-runoff model.

areal rainfall were reduced by 10% below the estimate of true areal average, and the parameter values in the model were optimized a third time. The three sets of optimized values for each of the catchments are shown in Table 3.

Table 2. Description of the selected parameters of the Boughton model used in the study

USMAX	Capacity of the non-draining component of the upper soil store (mm)
DRMAX	Drainage component of the upper soil store (mm)
SSMAX	Capacity of the lower soil store (mm)
SDRMX	Drainage component of the lower soil store (mm)
AIMP	Impervious area runoff factor; fraction of rainfall above threshold value that becomes runoff
BIMP	Threshold value for impervious area runoff (mm)
FO	Maximum value of daily infiltration rate when lower soil store is empty (mm/day)
FC	Lower limit of daily infiltration rate, approached as lower soil store fills (mm/day)
AAK	Shape parameter of daily infiltration curve
BASEF	Fraction of moisture in subsoil that becomes daily contribution to runoff from groundwater
AAC	Fraction of moisture in subsoil that drains out of system per day as deep percolation loss

Table 3. Effect of erroneous rainfall data on values of optimized model parameters
(Units of USMAX, DRMAX, SSMAX, SDRMX, BIMP, FO and FC are mm. Other parameters are dimensionless)

Model parameters	100% estimated daily areal rainfall used	Optimum values of parameters: Estimated daily areal rainfall increased by 10% — Parameter value	±Δ%	Estimated daily areal rainfall decreased by 10% — Parameter value	±Δ%
		Fifteen-Mile Creek Catchment			
USMAX	8·9	17·5	+97	7·4	−17
DRMAX	6·9	2·5	−63	5·1	−36
SSMAX	50·3	21·6	−57	55·6	+11
SDRMX	15·5	28·4	+83	13·5	−13
AIMP	0·289	0·096	−67	0·32	+11
BIMP	14·2	26·7	+88	11·9	−16
FO	101	43·9	−57	74·4	−26
FC	6·4	2·0	−68	4·6	−28
AAK	0·0035	0·0069	+97	0·0046	+31
BASEF	0·065	0·1711	+163	0·0843	+30
AAC	0·0441	0·0191	−57	0·0488	+11
		Buaraba Creek Catchment			
USMAX	13·0	14·7	+14	8·9	−31
DRMAX	8·6	9·9	+15	6·1	−29
SSMAX	48·5	42·2	−13	33·3	−31
SDRMX	25·9	29·5	+14	17·8	−31
AIMP	0·089	0·078	−12	0·113	+27
BIMP	6·4	7·6	+20	5·1	−20
FO	129	148	+14	165	+28
FC	3·8	4·8	+27	4·9	+28
AAK	0·0045	0·004	−11	0·0031	−31
BASEF	0·0197	0·017	−14	0·02	+2
AAC	0·0356	0·0408	+15	0·0323	−9
		Laidley Creek Catchment			
USMAX	8·9	14·5	+63	7·4	−17
DRMAX	5·3	8·1	+52	4·6	−14
SSMAX	73·9	42·4	−42	84·6	+14
SDRMX	19·1	9·9	−48	20·3	+7
AIMP	0·244	0·141	−42	0·278	+14
BIMP	13·7	20·8	+52	12·2	−11
FO	138	216	+56	122	−12
FC	3·8	6·1	+60	3·0	−20
AAK	0·0036	0·0021	−42	0·0041	+14
BASEF	0·0526	0·0301	−43	0·0601	+14
AAC	0·1885	0·1581	−16	0·1629	−14
		Tenthill Creek Catchment			
USMAX	11·7	13·0	+11	10·7	−9
DRMAX	8·6	9·4	+9	8·1	−6
SSMAX	164	151	−8	181	+10
SDRMX	15·2	16·5	+8	18·8	+23
AIMP	0·153	0·141	−8	0·127	−17
BIMP	32·0	34·8	+9	26·4	+17
FO	153	166	+8	128	−17
FC	6·4	6·9	+8	8·1	+28
AAK	0·0049	0·0047	−4	0·0058	+18
BASEF	0·098	0·0900	−8	0·1162	+19
AAC	0·4545	0·4916	+8	0·4105	−10

Table 3. *(Continued)*

Model parameters	100% estimated daily areal rainfall used	Optimum values of parameters: Estimated daily areal rainfall increased by 10%		Estimated daily areal rainfall decreased by 10%	
		Parameter value	±Δ%	Parameter value	±Δ%
		Flagstone Creek Catchment			
USMAX	18·3	19·6	+7	14·2	−22
DRMAX	11·4	12·7	+11	8·6	−24
SSMAX	73·4	69·6	−5	89·1	+21
SDRMX	25·4	24·1	−5	19·8	−22
AIMP	0·1	0·095	−5	0·115	+15
BIMP	38·4	40·9	+7	30·0	−22
FO	184	193	+5	143	−22
FC	2·5	2·5	0	2·0	−20
AAK	0·004	0·004	0	0·0049	+23
BASEF	0·0493	0·0468	−5	0·0606	+23
AAC	0·0754	0·0794	+5	0·0587	−22

Discussion

The results in Table 3 show the optimized values of model parameters that would have been obtained if the rainfall data were in error by ±10%. Changes to the parameter values are not uniform from catchment to catchment. The absolute values of percentage change in the 11 parameters averaged 46% for the Fifteen-Mile catchment, and averaged 10%, 13%, 19%, and 29% for Tenthill, Flagstone, Buaraba, and Laidley catchments, respectively. It is highly unlikely that the maximum change found in a small sample of five catchments in a single study area is the maximum possible change; so larger variations than occurred on Fifteen-Mile Creek seem possible.

The sum of USMAX and DRMAX represents the surface storage capacity of a catchment. Table 4 shows how the sums of the optimized values of these parameters change due to increases or decreases in rainfall input where the runoff output is fixed. When rainfall data were increased by 10%, the optimized sums of USMAX and DRMAX were increased by an average of 24% in order to keep the estimated runoff volumes as near to recorded runoff as possible. Similarly, when rainfall data were decreased by 10%, the optimized sums of USMAX and DRMAX were reduced by an average of 20% to compensate. It is noteworthy that the induced errors in optimized values of these parameters are likely to be twice as great as the errors in rainfall data. Table 3 shows that the induced errors in other model parameter values are of similar magnitude.

Table 4. Effect on estimate of surface storage capacity (sum of optimized values of USMAX and DRMAX) due to error in rainfall input

Catchment	Sum of USMAX + DRMAX (mm): Using estimated areal rainfall	Areal rainfall increased by 10%	Areal rainfall decreased by 10%
Fifteen-Mile	15·8	20·0 (+27%)	12·5 (−21%)
Buaraba	21·6	24·6 (+14%)	15·0 (−31%)
Laidley	14·2	22·6 (+59%)	12·0 (−16%)
Tenthill	20·3	22·4 (+10%)	18·8 (−7%)
Flagstone	29·7	32·3 (+9%)	22·8 (−23%)
		Average: +24%	−20%

Hall and Barclay (1975) suggest that errors in estimates of areal rainfall are likely to be of the order of 20–40%. This indicates that the optimized values of model parameters are likely to have substantial errors due to errors in the rainfall input in addition to any other errors from errors in the runoff or evaporation data. There is no uniformity in the changes in parameter values shown in Table 3.

Where parameter values have been fixed by calibration or other methods, there will be errors in estimates of runoff produced by the model if there are errors in the rainfall data used to make the estimates of runoff. When the rainfall data were changed by ± 10% in this study, changes in the total volume of runoff were noted (i.e. using the previously calibrated parameter values) before the parameters were reoptimized for the new rainfall input. The results are shown in Table 5.

Table 5. Effect on estimated volume of runoff due to error in rainfall input
(Units are mm depth of runoff during period of record used)

Catchment	Using estimated areal rainfall	Depth of runoff (in mm) Areal rainfall increased by 10%	Areal rainfall decreased by 10%
Fifteen-Mile	1871	2301 (+23%)	1477 (−21%)
Buaraba	917	1169 (+27%)	705 (−23%)
Laidley	1878	3252 (+73%)	1511 (−20%)
Tenthill	423	537 (+27%)	323 (−24%)
Flagstone	292	316 (+8%)	165 (−43%)
		Average: +32%	−25%

Nine of the 10 changes in total volume of runoff are greater than 20% for a change in rainfall input of 10%. The percentage change in estimated runoff, due to 10% change in rainfall input, will be different in areas that are wetter or drier than the study area, and no general relationship is suggested. However, the results confirm earlier results by Boughton (1981) that errors in estimated runoff can be much higher than the errors in rainfall input.

Conclusion

Information available in published literature shows that errors of 10–20% in estimating areal rainfall over a catchment can be regarded as normal, and errors up to 60% can occur with strong winds or in mountainous catchments.

The effect of errors in rainfall data on the optimized values of parameters in a lumped-parameter rainfall-runoff model were studied by deliberately making changes of + 10% and − 10% to the rainfall data. Using data from five catchments, 88–455 km² in area in south-east Queensland, it was found that errors of ± 10% in rainfall input can produce changes of much higher magnitude in optimized parameter values. Changes in optimized parameter values averaged 49% on one catchment due to a ± 10% change in rainfall. The sums of the capacities of the two moisture stores which simulate surface storage capacity in the model were found to increase by an average of +24% when rainfall was increased by 10% and by an average of −20% when rainfall was reduced by 10%.

If the estimates of 20–40% error in determining areal rainfall are correct, then it seems unlikely that mathematical optimizing of parameter values in lumped-input models will lead to values that have any reliable relationship with physical characteristics of the catchment areas. Sensitivity analyses of the effects of errors in rainfall data on rainfall-runoff models seem desirable.

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