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TIME SERIES RAINFALL - RECENT DEVELOPMENTS AND APPLICATIONS

Robert J. Henderson

River Basin Management Group
WRc Engineering
Swindon.
Tel. 0793 488301

Introduction

An increasing number of drainage problems require some knowledge of the day to day hydraulic performance of existing sewer systems as well as that during extreme (design) events. WASSP-SIM is frequently used in the analysis of combined systems with overflows outfalling to watercourses having differing capacities to accept periodic discharges. In order to establish the frequency, rates, volumes and therefore impact of storm overflow discharges it is necessary to characterise the rainfalls occurring during a representative year. This need prompted WRc Engineering to examine potential applications of rainfall series and produce time series of fine resolution rainfall, suitable for input to WASSP for a 'typical' year in two U.K. regions. This work is one product of the River Basin Management research programme coordinated by WRc Engineering and described more fully in an accompanying paper (1).

Potential applications.

Potential applications of an annual series include:

i) sewer flow quality modelling,
ii) storm overflow analysis,
iii) detention tank design,
iv) pump station optimisation studies,
v) prediction of overpumping requirements during renovation works,
vi) extension of the design storm range to below 1 year, to assess surcharge frequency in overloaded systems.

The need for two forms of the rainfall series was identified; one having rainfall and dry periods in chronological order for continuous simulation modelling, and a second having rainfalls crudely ranked in order of decreasing severity, thereby reducing computing demands in certain applications. In addition, seasonal time series are contemplated and may be appropriate for short-term investigations such as overpumping during renovation or assessment of overflow spill volumes during periods of low flow in receiving streams.

Derivation of the annual rainfall series.

Autographic raingauge data digitised at 1 minute intervals were available from 5 sites, 2 in the South West and 3 in the South East, for up to 34 years of record at each site (see Table 1). These data were in compressed form and provided a continuous record of cumulative rainfall total in hundredths of millimetres for each day, together with information on inter-event dry periods and SMD values.

A length of record adequate for analysis was obtained by concatenating the records within each homogeneous precipitation region identified by earlier research (2). Thus the South East sites were linked to form 98 years of record and the South West sites formed 30 years.

3.0 Future data base developments

3.1 Water Authorities in conjunction with WRc are considering requirements for digital data bases for sewerage systems. As well other aspects of sewerage system performance these data bases will hold information relating to pipe location (grid reference to resolution of 1m), levels, pipe sizes and lengths, manhole details and there is no reason why such parameters as roughness coefficient and contributing impermeable area should not eventually be included.

3.2 It is expected that these data bases will be introduced over the next year or two and total coverage will be achieved over the next 5-10 years.

4.0 Links with WASSP

4.1 When established, digital data bases will hold much of the pipe data required for the WASSP programs and a large proportion of the keying-in of data could be avoided if direct data transfer could be achieved.

4.2 In order to achieve data transfer it will be necessary for the WASSP programs to accept the pipe length reference system of the data base. In using WASSP to model systems it is not necessary to enter details of every individual pipe length, indeed the programs would not have capacity to accept this for most networks. Individual pipe lengths are therefore grouped into pipes for modelling purposes and this grouping will vary according to the detail in which the network is being modelled and what proportion is being modelled at any one time. It is therefore not possible to get over the pipe referencing problem by giving each pipe length two references, one for data base and one for WASSP and providing cross reference between the two. If direct links between WASSP and data bases is to be achieved, significant changes in the way WASSP handles data will have to be made.

5.0 Conclusions

5.1 The pipe length referencing systems required by WASSP and digital data bases are incompatible.

5.2 There would be substantial advantages in facilitating the hydraulic analysis of sewerage systems if direct transfer between the two systems could be achieved.

6.0 Recommendations

6.1 It is RECOMMENDED that consideration be given to the feasibility of developing the WASSP programs to enable them to accept a pipe length reference of the form used in digital data bases and allow the direct input of data from such bases.

Statistical procedures were developed to analyse the record from each region on an event-by-event basis. A 2 dimensional frequency distribution of rainfall event depths and durations was derived for each of the complete data months (see Fig. 1). A 13 x 13 matrix of depth-duration classes was employed, with depths in the range 0.1 to 60 mm and durations between 0 minutes and 3 days. A similar dry weather duration-frequency analysis was also performed.

Having characterised the rainfall events on a monthly basis, two alternative approaches were investigated in deriving a 'typical' year: i) generate synthetic rainfall patterns based on the frequency analyses or ii) select sequences of historic rainfall from the record which best resemble the frequency analyses performed for each month class. The first approach would necessitate further analysis of individual hyetograph shapes, taking season into account (i.e. to convert 'blocks' of rainfall to realistic profiles). This was beyond the scope of this initial study but may be adopted for any future external research project. The second approach was the more straightforward and has the merit of using historic profiles.

Therefore at each site the depth-duration-frequency tables produced for individual months were analysed and compared with the overall summary for each month class. An objective procedure was developed to allow selection of the 12 individual months which most closely resembled the overall pattern in terms of

- o the monthly average rainfall,
- o the event duration-depth-frequency analysis,
- o the inter-event dry period distribution.

Each annual series consists of a selected sequence of the most typical months having a total rainfall equating to the SAAR.

The basic data were then screened to remove insignificant events (<0.5 mm total or <0.1 mm/h average intensity) and converted to WASSP input format (some 210 discrete events for the S-W series).

Application of the time series.

The S-W series has been applied to 3 catchments of differing characteristics and, based upon overflow volumes noted, the series was then crudely ranked in order of descending severity.

The ranked series has been used to assess various storage options at a tank overflow on the Gt. Harwood combined sewer system where water quality is currently being monitored. The catchment has a population of 12500, a total impermeable area of 65 ha, comprises 350 pipes and produces a peak 2 year design flow exceeding 4 m /s. Maximum carry on flow downstream of the overflow is approximately 280 l/s. Table 2 illustrates the effectiveness of modest storage in reducing total spill volume and frequency during a year, thereby containing the worst polluting discharges. Optimal sizing of storage can thus be aided by using a time series.

On a practical point, to run the 99 most severe events during the year for this catchment required 10.9 hours of CPU time on a VAX 11/780 computer. Not all catchments would require simulation of so many, smaller events and it is envisaged that an earlier 'cut-off' point could be established. Furthermore it may prove unnecessary to run each event but select (say) every third one.

In a second investigation, which forms one of the Sewerage Rehabilitation Manual pilot studies, it was realised that the choice between upgrading solutions available could not be made solely on the basis of capital costs alone. Information was also needed on the running costs of the sewer system (pumping requirements) and the amount of storm sewage spilled. The time series rainfall

analysis provided the data required.

Full details of the analytical methods and practical applications of the series may be found in a forthcoming WRc report.

Conclusion.

Annual series of rainfall applicable to two UK regions have been developed and applied using the WASSP model. These allow assessment of overflow spill volumes on a realistic basis and aid in planning the upgrading/rationalisation of overflows. The series also have several potential applications in sewer system operation. A more comprehensive investigation is seen to be necessary in the future to produce series which can be readily and confidently applied to other UK locations.

References.

1) Henderson R.J. "Water Quality Modelling with WASSP" - paper presented at the WAPUG Autumn meeting, Birmingham 1985.
2) Wigley T.M.L. et al "Spatial patterns of precipitation in England & Wales" J. of Climatology Vol 4, 1984.

Acknowledgement.

Much of the data analysis upon which the rainfall series are based was performed by Mr. I.N. Vaye, formerly of Birmingham University, during his MSc project placement with WRc.

Table 1 - Summary of site description

SITE	YEARS OF RECORD	MISSING DATA (days)	AVERAGE ANNUAL RAINFALL (mm)	APPROXIMATE ELEVATION (mAOD)
St Mawgan	1956-1967	27	990	76
Rhoose	1958-1975	94	960	61
Abingdon	1944-1975	254	600	76
Farnborough	1941-1971	155	660	75
Hampstead	1941-1975	1385	650	100

Table 2. Summary of overflow spill analysis - Gt. Harwood

	Storage volume at overflow (m^3)		
	nil	275	550
No of events causing spill	64	30	18
Total annual spill (m^3)	33500	15300	10600
Peak rate of overflow (m^3/s)	2.57	2.30	1.10
No of events where overflow rate exceeded 0.5 m /s	19	12	8