WORK OF THE URBAN POLLUTION MANAGEMENT GROUP - RAINFALL DEVELOPMENTS

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1. The Urban Pollution Management Group

The Urban Pollution Management Group (UPM) co-ordinates a programme of research for the development of an effective methodology for the control of urban water pollution. The basic philosophy behind the programme is the need to control discharges from CSO's and other urban sources, due to the impact such discharges may have on urban receiving waters. The UPM philosophy is that the extent of control required is such so as to render the impact acceptable in meeting the agreed uses of the receiving water. For control to be properly applied, understanding of the nature of the impact is necessary, together with knowledge of the contributory processes in both the urban drainage system and the receiving water.

The approach is very much one of achieving Environmental Quality Standards (EQS) to meet agreed Environmental Quality Objectives (EQO), rather than that of fixed emission standards or purely technology based solutions. EQS will become statutory in 1992.

2. The Setting of, and Compliance, with Standards

Intermittent storm related discharges are poorly understood in terms of their character, effect and control. To achieve EQOs they must be managed effectively and in a manner compatible with continuous discharges (e.g. from sewage treatment works). If the environmental impact of intermittent discharges is to be properly controlled, the effect of short term changes in discharge pollutant concentration, coupled with duration of exposure, and return period need to be understood. Also appropriate environmental quality standards for the receiving waters must be derived. Work has already been undertaken in the UPM programme in this area and draft standards for dissolved oxygen and ammonia have been proposed.

A major aspect of the UPM programme is the development of modelling tools to assess compliance with these standards. Three models are required:

(a) a model of the sewer system to predict the polluting loads discharged to the receiving environment;

(b) a model of the receiving water to simulate the behaviour of discharged pollutants; and

(c) a model of the sewage treatment works to predict the quality of effluent discharged during storm periods.

All of these models are under development. The sewer quality model MOSQITO[1] has been comprehensively reported to this forum previously. The stream impact model MIKE 11[2] is capable of accepting as input, the output from MOSQITO. The dynamic sewage treatment model is called STOAT[3] and is currently under development in prototype form.

3. Rainfall Inputs

The UPM models are all driven directly or indirectly by rainfall inputs. The currently available rainfall inputs for such models have several limitations in respect of providing data for water pollution management.

The current design storm algorithms built into WASSP and WALLRUS are based on extreme value rainfall statistics and, whilst easy to use, do not allow the generation of rainfall profiles of less than a one year return period. Use of design storms is inappropriate where spills occur frequently. Other problems with synthetic storms include their shape, accounting for previous rainfall, and the truncation of the event at the beginning and end of the storm.

The development of annual UK Time Series Rainfall[4] has allowed the assessment of storm discharges which occur more frequently than once per year; i.e., during a 'typical year'. The limitations of this method are well known. In particular, the regionalisation procedures are relatively crude. Also, the series do not contain extreme events.

The use of historical rainfall data, supplied by the Meteorological Office, will undoubtably give valid results, although a number of problems exist:

- suitably long records of one minute data are available for only a few UK locations;
- the rainfall data is increasingly costly to buy;
- developing a local time series is labour intensive;
- running the simulation models for a large number of historic storms is computationally demanding and is unlikely to be practical unless gross modelling simplifications are made.

The Coastal Sewerage Research Programme at WRc has concentrated on this area to try and overcome these problems and develop procedures based on historical rainfall records. Several procedures have been developed, including the use of local hourly rainfall and disaggregating the data into five minute values. Sampling of representative storms allows a design set of events to be produced which can be run through the simulation models. In addition, simplified sewer flow modelling methods have been devised to allow the full simulation of long chronological series, thus taking account of successive storms.

Current work has taken a more wide ranging approach to the problems of providing a suitable rainfall input to models. The work described previously by Hydraulics Research[5] is one approach. This is to base the choice of rainfall data on synthetic storms, but to expand the range of conditions which are represented by the current design storms. This allows the user to use a small number of storms to predict the behaviour of the catchment under a wide range of conditions.

An alternative approach developed by WRc is a Stochastic Rainfall Generator Model (SRG). This model can produce a series of rainfall data, for any length of time and for any location within the UK. It is, therefore, statistically equivalent to a local historical rainfall series.

4. The Stochastic Rainfall Generator Model

Development of the SRG was co-ordinated by WRc and carried out in the Department of Civil Engineering at The University of Newcastle-Upon-Tyne. The funding was provided by the Foundation for Water Research.

The basic requirement at the outset was to develop a model which was able to generate a rainfall time series for any given UK location for intervals down to 5 minutes. The model selected was the Neyman-Scott Rectangular Pulses Model, as developed by Rodriquez-Iturbe et al[6].

The model was developed and parameter estimates for the model were calculated and tested using historical rainfall data. Rainfall data were available from 120 Meteorological Office stations, which broadly covered the whole of the UK. One minute, hourly and daily records were used. Significance testing of the model output was performed throughout the model development. This included assessing the fit to historical hourly and daily data and ensuring that extreme events were adequately represented.

A major requirement was to find a regional/seasonal model that could be used to predict the parameters within the Neyman-Scott model for locations where rainfall data do not exist or, where data are for too short a time period to be

confident that they are representative of the area. The following variables were used to describe the regional variation of rainfall:

- Altitude
- North O/S grid reference
- East/West effect
- Distance from the coast.

Seasonality was accounted for by creating different parameters for each month of the year.

Input necessary to estimate the parameters within the model, consist of the four regional rainfall variables above, and mean monthly rainfall (which is easily obtained from published Meteorological Office tables). Additional information which may be necessary if the site is likely to be within a micro climate, is the daily rainfall from a local rainguage.

Output from the SRG model is in the form of hourly rainfall totals. A disaggregation technique has been developed to produce 5 minute data which would be necessary for input into models, such as WALLRUS-SIM. The disaggregation model is similar to that used by Ormsbee[7]. The output from the disaggregation method has been successfully tested on two long series of one minute historical rainfall data, taken from sites in the west and east of the UK.

The full model definition and fitting procedures to hourly and daily rainfall data; the extreme event analysis; and the disaggregation technique are described in FWR Report Number FR0127[8]. This will be available from the Foundation for Water Research in early 1992.

5. Use of the Stochastic Rainfall Generator Model

The SRG produces a long term, local hourly rainfall time series which is, effectively the equivalent to a local hourly historical series. The output from the SRG is therefore, as versatile as a long historical rainfall record.

Previously it has been mentioned that WRc have been exploring several options to develop procedures which allow the effective use of historical rainfall data. Research is ongoing and several techniques are already available to make more efficient use of long rainfall series. However, the form of rainfall input depends on the intended use and the form of compliance that is to be met. Clearly, the SRG is a valuable tool in helping decision making to achieve compliance with consents and levels of service.

6. References

1. PAYNE J A and A D PARKINSON "MOSQITO - The Royton Experience" WAPUG Autumn Meeting Nov 1990.

2. DANISH HYDRAULIC INSTITUTE "Mike 11 User Guide" 1990.

3. STIMSOM K "Dynamic Modelling of Sewage Treatment Works" WRc Report ER 374E. April 1989.

4. HENDERSON R J "Rainfall Time Series for Sewer System Modelling" WRc Report ER 195E 1986.

5. RAINEY C M and M OSBORNE "Design for Storage Using Synthetic Rainfall" WAPUG Autumn Meeting Nov 1991

6. RODRIQUEZ-ITURBE I, COX D R AND ISHAM V "Some Models for Rainfall based on Stochastic Point Processes" Proceedings of the Royal Society London (410) pp269-288 1987.

7. ORMSBEE L E "Rainfall Disaggregation Model for continuous Hydrologic Modelling" Journal of Hydraulic Engineering 115 pp507-525 1989.

8. COWPERTWAIT P S P, J A MAWDSLEY, A V METCALFE, P E O'CONNELL and J L THRELFALL "Stochastic Generation of Rainfall Time Series" Foundation for Water Research Report FR0127 Dec 1991.

Paper 6: Work Of The Urban Pollution Management Rainfall Group (J Threlfall, WRc)

B Andoh, Bingham Cottrell : The stochastic rainfall generator is based on 30 years of record. If it was used to generate 60 years of record would it simply repeat the first thirty years? Would this affect the accuracy?

Ans : The second 30 years would contain different events from the first 30 years, as different random numbers would be used. However the events would not represent the more extreme events which would be expected in a 60 year period. The method was really intended for looking at return periods of up to 1 year.

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J Payne, CIRIA : It is not really possible to sample from the time series as the inter-event periods are also needed. The use of the method probably has to wait until very fast computers are available so that the full series can be run.

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D Walters, M W Barber : What is a stochastic generator? What is desegregation? Will you be selling some software?

Ans : A stochastic generator is based on selecting random numbers from a range of values for several parameters. Desegregation splits up the data into shorter timesteps. It is a form of interpolation but again using a random number to modify the values. No, we will not be selling software. A report will be produced by FWR in February. This will contain enough information for someone to develop software if they wish to do so.

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B Andoh, Bingham Cottrell : Will the report contain all of the necessary equations?

Ans : It should do. Some of them may be in other reports which are referenced from this report.

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John Packman, Institute of Hydrology : The model includes a lot of parameters. Will the report include tests on the correlation of the output with the measured rainfall data? How good would the model be based on daily data?

Ans : Yes. A lot of testing has been carried out and the results will be in the report. If you had a large amount of data, say almost 30 years, it would be better to use the data rather than the model.