SEWER QUALITY MODELLING

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1. BACKGROUND

The EC Urban Waste Water Treatment Directive (UWWTD) requires that member states ensure that agglomerations with population equivalents of 2000 or more are provided with sewage collecting systems. It also states that the design, construction and maintenance of sewage collecting systems shall be undertaken in accordance with the best technical knowledge, not entailing excessive costs, notably regarding, among other things, the limitation of pollution of receiving waters due to combined sewer overflows.

In the UK, a framework[1] for implementing the sewerage requirements of the Directive has recently been prepared by the NRA following consultation with the DoE, Water Services Association and the UWWTD Implementation Group. Three different approaches have been suggested for the procedures to review CSO discharges to freshwater. These approaches require different levels of sophistication to determine appropriate design criteria and are related to the significance of the discharge.

Where the discharge has low significance, a simple discharge control method such as Formula A is deemed to be adequate. A simple impact assessment model (for example, QUALSOC, CARP) and a sewer hydraulic model will be required for medium significance, where dilution in the receiving water is less than 8:1. For the most complex type of study, where there are major discharges to a sensitive water course, the application of hydraulic analysis and water quality modelling in both the sewerage system and the river will be required. Such a study will be required for catchments where there is low dilution available in the receiving water; extensive interaction with other discharges; a large population equivalent (i.e. greater than 10,000); and where the receiving water has a high quality use requirement.

This paper is concerned with explaining the planning procedure which is being developed to meet the demands of this latter type of investigation.

2. POTENTIAL APPROACHES FOR MODELLING URBAN WASTEWATER QUALITY

Deterministic and stochastic models provide two potential approaches for modelling the quality of flows within a wastewater transport/treatment system and the subsequent impact of those flows on the receiving environment. In a deterministic approach the processes modelled are understood and represented by fundamental or empirically based mechanistic mathematical equations. Hence, there is a fixed relationship between inputs and output. By contrast, stochastic, or statistically based, models allow the apparent random fluctuations in natural systems to be reproduced where there may be little understanding of the processes involved.

Examination of existing data shows a high degree of variability in the quality of urban runoff and sewer flow[2]. Uncertainty in the current understanding of these systems suggests that a stochastic modelling approach would be attractive. However, the main reason for wanting to model sewer flow quality is to assess compliance with environmental standards for new and upgraded systems. By definition, stochastic models cannot be used to examine this type of "what if" scenario, as the system itself will be altered and the nature of the variability between inputs

and outputs becomes unknown. Therefore, under current circumstances, a deterministic approach is preferable and has been adopted in the main modelling tools produced under the Urban Pollution Management (UPM) programme.

It is still necessary to take account of the variability of rainfall inputs. This brings into focus the demands of detailed deterministic models used for a wide variety of background and input conditions. Hence, there is a need to develop simplified deterministic models which can be calibrated against detailed model results. These simplified models can then be used with long rainfall sequences to assess system compliance. This forms the basis of the detailed UPM planning procedure which is described below.

3. THE URBAN POLLUTION MANAGEMENT (UPM) APPROACH

The UPM procedure recognises that an integrated approach is required when undertaking the most complex type of study. To simulate wet weather discharges, comprehensive rainfall inputs should be used with a sewer quality simulation model. Outputs from the sewerage model, along with outputs from a sewage treatment works model should be input into a dynamic receiving water quality impact model.

An objective planning framework for both surface water and combined sewers is required to limit discharge to loads and locations such that the assimilative capacity of the river is not exceeded. In the UK, the occurrence of the first foul flush effect has been widely reported[2]. This effect must be modelled to achieve short term river quality criteria in relation to oxygen depletion and acutely toxic substances, such as Ammonia, to allow desired uses to be achieved. A further reason for requiring to understand the short term temporal variations of spill quality is the sizing of detention tanks. Where detention tanks are provided for pollution control, it is important that the requisite polluting load is retained within the minimum storage volume to minimise construction costs.

To meet this requirement, deterministic "pollutograph" sewer quality models have been developed, which can model BOD/COD, total Ammonia and various fractions of suspended solids. MOSQITO, developed by HR Wallingford uses WALLRUS to provide hydraulic calculations. MOUSETRAP, which is being developed by The Danish Hydraulic Institute, SAFEGE (France), VAV (Sweden) and WRc, uses MOUSE to provide the hydraulics. Both models provide discharge outputs in the form of pollutographs which, in conjunction with the output from a dynamic sewage treatment works model, (such as STOAT which has been developed in prototype form by WRc) can be input into a dynamic receiving water impact model, for example, MIKE 11.

MIKE 11 allows the impact of all types of wastewater discharges to be assessed. This may then be compared to appropriate intermittent environmental standards. These standards have been developed by the NRA and are based on laboratory ecotoxicological work, verified by field observations. Table 1 summarises the intensity/duration/frequency criteria identified for dissolved oxygen levels.

Table 1 - Water quality criteria for the protection of aquatic life during intermittent oxygen depletion events

Return Period	1 hour	24 hours
Continuous exposure	9	9
1 month	3.5	5
3 months	3	4.5
1 year	2.5	4
Instantaneous minimum of 2mg/l DO concentrations in mg/l		

The major strength of this approach is that the user can develop a full and detailed explanation of what occurs in all elements of the system. Once the models are built and verified, it is possible to look at a wide range of options for the whole catchment quickly and easily. This integrated approach also directly addresses meaningful criteria for the first time (i.e. protection of the ecology of the system) and therefore, gives high confidence in the effectiveness of the solutions generated. Ancillary structures may be designed to these requirements and need not have a large built-in factor of safety.

4. FUTURE DEVELOPMENTS

Examination of the application methodology highlights that, in practice, it is not feasible to run these detailed models for large numbers of storm events. Hence, a working methodology is being developed which incorporates simplified relationships for the response of the sewerage system, the treatment works, and the receiving water. Detailed models remain an essential part of the UPM approach and will serve to calibrate these simple relationships to evaluate compliance with performance criteria for a wide range of temporal and spatial characteristics. This procedure will be published in the Urban Pollution Management Manual in 1994.

5. CONCLUSIONS

NRA guidelines require detailed quality simulation modelling of sewerage systems to be undertaken under specified conditions. A methodology has been developed that allows the water quality impact of wet weather discharges to be assessed. Stochastic models are not suitable for this detailed approach, and, therefore, dynamic deterministic models are needed. MOSQITO and MOUSETRAP are examples of sewer flow quality models which offer the engineer this capability.

Fully integrated, reliable solutions can be developed which will optimise both detention tank size and spill loadings and will permit the development of cost effective designs. The NRA requirements may be seen as minimum criteria for the use of the detailed models. Using more detailed planning models may increase the investigation and design costs, but will lead to greater confidence and potential cost savings in the implementation and construction of the overall upgrading scheme.

6. REFERENCES

1. NATIONAL RIVERS AUTHORITY. **AMP(2)/Effluent quality, NRA Guidance Note for Preparation Work for AMP(2).** 1993.

2. THORNTON R C AND SAUL A J. **Some quality characteristics of combined sewer flows.** The Public Health Engineer, Vol 14, No 3. 35-39. 1986.

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Question

Camylyn Rainey, Wallingford Software

What problems were encountered with model simulation times would it not be better to consider analysis of the rainfall data rather than model results?

Martin Osborne's interpretation of question as Chairman, are the long run times associated with long time series pushing us away from using detailed models? Can we stay with detailed models if we find another way of using the rainfall?

Answer

The UPM approach is not saying do away with the detailed model, they will be used to calibrate the simplified relationships. The same way SMARTS has been developed to run a long time series to optimise results, the UPM approach is saying the same thing. Calibrate first with a detailed model also we are no longer looking at a single model we have at least 3 models.

Question

Mark Bottomley, Montgomery Watson

Are you concerned that the use of simplified models may compromise the effectiveness of the pollutant model. Flow characteristics maybe so completely different in terms of silt movement and the complex hydraulics that pollutant generation and transport predictions are meaningless?

Answer

The UPM group is not sure at present they are looking at simplified models as well as detailed models. It may be that they are not effective and cannot be used.

Question

David Balmforth, Sheffield Hallam University

Do you envisage the verification of quality models in the same way that we now verify quantity models, and if so has the industry got a handle on the resources and technology required at the moment?

Answer

Possibly not at the moment but I am sure that back in 1981 when WASSP first came out the same doubts and concerns were around. Maybe not now be a straight civil engineering job, will now include water quality scientists.

Jim Allen could usefully comment on MOSQITO verification.

Comment

Jim Allen, Severn Trent Water

I have verified the DWF model only loosely verified the storm model. There is a long way to go, particularly on the sampling side, before the technology and expertise is upto the standard of velocity and depth measurement techniques.

Unless the contractors and the industry as a whole gets together and sorts out the management of sampling then we won't get very far forward.

Comment

Chris Jefferis, Dundee Institute of Technology

We are currently carrying out MOSQITO verification of a catchment in Perth with data gathering for STOAT. STOAT is 12 samplers and 8 flow monitors with MOSQITO using 12 flow monitors and 6 samplers.

There is a great deal of sampling and a great deal of testing involved, sampling is at 2 hourly intervals for STOAT in the treatment works.

Comment

John Farrer, MW Barber

There has been a lot of talk about scientific methodologies for evaluating overflow operation and impact on a water course. I am sure though that there is a lot of basic information that needs gathering on the 25,000 overflows known to exist, particularly their frequency of operation. This would back up the TSR spills we are predicting in our models at present where the overflow is only placed in 1 of 4 broad categories.

Question

Ian Garside, Montgomery Watson

I am concerned about the cost of all this sampling, are there any lessons to learn from our friends on the continent? Have they been down this route already?

Answer

They are much in the same position as we are in the UK. It is all new and its all very expensive, there are not short cuts.

Question

David Walters, MW Barber Group

When measuring at CSO for water quality where do you take the samples, in the chambers, over the weir, in outfall pipe.

Answer

Martin Osborne answered: referring to Chris Jefferis paper on treatment factors of unity it could be in the pipe upstream of the overflow.