Effective environmental regulation to maximise the benefits of integrated wastewater management

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Abstract On the 25 November 1999, the Secretary of State for the Environment in England and Wales announced the outcome of the water companies' third Periodic Review. As a result, a major environmental investment programme will be completed during the period 2000/2005. Overall in England and Wales, it is planned that almost 3,600 km of rivers will be protected or improved and 3,800 unsatisfactory CSOs will be improved to allow receiving water objectives to be met. This means that over the next 5-year period an average of nearly 18 discharges will be improved every week. The implementation of the programme will involve a large workload for the Environment Agency in planning and authorising the individual schemes for delivery by the water companies. The paper illustrates how the Urban Pollution Management procedure and associated environmental standards are to be used to underpin the Environment Agency's policy, to encourage the use of integrated wastewater planning and, as a result, ensure that the anticipated environmental improvements will be delivered.

Keywords Combined sewer overflows; environmental standards; integrated wastewater management; policy; urban pollution management; wastewater modelling

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Introduction

At the first Interurba Conference in 1992, a paper by Clifforde and Johnson (1993) presented the approach that was to be adopted in the UK to develop an effective control methodology for wet weather urban wastewater pollution. The methodology, called Urban Pollution Management (UPM), was based on the results of a previous major national research programme to investigate the causes, nature and impact of wet weather discharges from, in particular, Combined Sewer Overflows (CSOs). The methodology was documented in 1994 as the UPM Manual (FWR, 1994). The first objective of this paper is to review the uptake and subsequent evolution of the UPM Manual methodology since the original Interurba Conference.

The second objective is to present the Environment Agency's policy for the use of the UPM approach to develop integrated wastewater solutions in a major water industry investment programme over the next 5 years. Finally, the paper will consider how further developments in integrated wastewater management can assist in the implementation of environmental policy by reflecting the needs of evolving environmental legislation.

Evolution of the UPM methodology

The roots of UPM date back to the early 1980's when it was recognised that an integrated planning methodology was required that gave equal emphasis to all aspects of urban wastewater system performance, including environmental impact. An approach that considered the whole of the urban wastewater system would allow the maximum value to be derived from the available funds for asset improvement. The early efforts (WRc, 1983) acknowledged the three facets of sewerage performance – flooding, structural and pollution – but were only effective in addressing the first two of these.

The industry wide UPM research and development programme, commencing in 1984, set out to meet these needs in a comprehensive and objective manner. The complexity of the issues to be addressed meant that the programme took some ten years and considerable resources to complete. The principal product was the Urban Pollution Management Manual, 1st edition (UPM 1), which was produced by the main contractor, WRc, and published by the Foundation for Water Research in late 1994 (FWR, 1994).

On release, the environmental regulator supported its use in principle, whilst the attitude of the water utilities varied from enthusiastic and widespread application to extreme caution and reluctance to move from tried and tested methods. Nonetheless, after 3 years of implementation, sufficient experience had been gained in the application of UPM and enough development of software tools had occurred to warrant an update of the Manual. However, it was soon agreed that a comprehensive reworking of the original document was called for, together with an improved method of product delivery. The second edition of the UPM Manual (UPM 2) was published in October 1998 (FWR, 1998) as a CD-ROM.

At a very early stage in the development process the basic, major tenets of UPM were established to be:

- That the urban wastewater system, comprising the sewer system, the treatment plant and the receiving water, should be treated as a single entity in which change to one part has implications for the other parts that should be taken into account during the planning process.
- That the whole approach is underpinned by wet weather environmental standards, with an appropriate modelling process being used to demonstrate compliance of the proposed scheme with these standards.
- That the form of modelling employed in a study should be appropriate to the technical needs of the study. The minimum level of modelling should be adequate to address the technical requirements of the study area and result in a "safe" solution which would be sure to meet environmental requirements. More sophisticated planning may be used to refine the "safe" solution and reduce overall costs without compromising the level of environmental protection.

These basic tenets remain as the foundation stones of UPM 2. The changes that have occurred between the two documents are as a consequence of technical developments and experience gained over time. These may be summarised as follows:

- Stronger distinction is made between regulatory policy matters and technical procedural issues.
- Allied to the above, UPM 1 made extensive reference to circumstances and documents that were specific to England and Wales, UPM 2 has been written in more general terms to be applicable both at other locations where relevant requirements occur and over a longer period of time.
- UPM 1 placed great emphasis on the use of the so-called Fundamental Intermittent Standards. In UPM 2, information is presented for a wider range of environmental standards, reflecting more recent developments in knowledge and thinking. UPM 2 also provides information on planning methods to apply these standards, without dictating which should be used.
- At the time of drafting UPM 1, the experience available to provide guidance for planning and executing integrated urban catchment studies was limited. By the time of UPM 2, the body of experience had increased considerably and it was possible to strengthen many sections of the document. In particular, better guidance was able to be given on gaining maximum value from existing data sources; how to collect additional data; and, in recognition of the practical time constraints which often exist in the real world, a "confirmed planning approach" was introduced which assisted users in identifying the optimum level of modelling to adopt at the outset.

- Several modelling tools were developed in the UPM Research Programme to plug gaps in the suite of tools available to planners seeking to implement the UPM procedure. Consequently, use of these specific tools, and others evaluated during the R&D programme, was recommended in UPM 1. Market considerations have dictated that alternatives to these commercial products have been developed in the intervening period. Hence, UPM 2 no longer offers guidance in terms of the use of specific modelling products, rather it identifies the requirements and capabilities of tools to achieve specific objectives. The consequence of this change is the loss of some detail in the guidance that can be given, which must now be found in software user documentation.
- One of the tools originally developed to support implementation of the UPM Procedure was SIMPOL. SIMPOL is a spreadsheet based, simplified, integrated urban pollution model. In UPM 1, users were provided with instructions on how to build their own spreadsheet SIMPOL models. However, this proved to be a time consuming and complex process for many users. In consequence, an improved version of SIMPOL has been provided in UPM 2, in electronic format, as part of the improved presentation of the document.

UPM 2 provides technical guidance on the choice of environmental criteria to protect beneficial uses of receiving waters from the impact of intermittent wet weather discharges. These criteria have a sound scientific basis or are commonly used in the UK. UPM 2 presents a range of wet weather standards to protect beneficial uses of receiving waters. The values presented in UPM 2 are illustrative of the type of criteria that could be used. An environmental regulator may choose to vary the values identified in UPM 2 or apply alternative forms of environmental criteria. Hence, the identification and agreement of environmental requirements by the environmental regulator and the discharger is one of the key initial planning steps in carrying out a UPM study.

Wet weather discharges may affect river water quality for relatively short periods of time. However, short term, high concentration events can have a disproportionate impact upon river aquatic life. Furthermore, the quality of a river during these events may not be related in any simple fashion to the more general quality of the river. UPM 2 identifies two approaches to protect river aquatic life from wet weather pollution episodes.

- *Fundamental Intermittent standards* (FIS) which are directly related to the characteristics of events which cause stress in river ecosystems. These standards are expressed in terms of concentration-duration thresholds with an allowable return period or frequency.
- *High percentile standards* (such as 99 percentiles) based on an extrapolation of the 90/95 percentile thresholds from the Environment Agency's Rivers Ecosystem (RE) classes that are used to plan and assess river quality.

The FIS were developed for UPM 1 from ecotoxicological information based on field and laboratory trials. The approach is based on the objective of no long-term detrimental effects on an aquatic ecosystem and no fish mortality for wet weather pollution episodes up to 1-year return period. FIS take the form of concentration/duration/frequency criteria to represent a concentration of Dissolved Oxygen or Un-ionised Ammonia that cannot be exceeded. Identified duration thresholds are 1, 6 and 24 hours and return periods (of the concentration and duration) identified are 1 month, 3 months and 1 year. UPM 1 identified a single set of standards to provide protection to all forms of freshwater aquatic life for pollution episodes up to a return period of 1 year. Subsequent research has been utilised for UPM 2 to identify 3 sets of standards to provide the same level of protection to 3 ecosystem types:

a) sustainable salmonid fishery;
b) sustainable cyprinid fishery; and,

c) marginal cyprinid fishery.

The specific criteria and associated applications procedures are fully reported in UPM 2. In practice, the tabulated standards are generally modified by using correction factors for individual sites and events to account for background environmental conditions and interaction between pollutants. This process has been improved in UPM 2. Typically, the criteria to be met for a sustainable salmonid fishery are more onerous than those for a sustainable cyprinid fishery under similar conditions. Tables 1 and 2 present the full suite of FIS. The standards identified for a sustainable cyprinid fishery are identical to the single set of FIS identified in UPM 1.

As an alternative to FIS, UPM 2 identifies 99%ile criteria related to Rivers Ecosystem (RE) class that have been derived by the Environment Agency. These values, presented in Table 3, are for BOD, Total Ammonia and Un-ionised Ammonia.

It is recognised that, while comparable levels of environmental protection provided by FIS and the 99%ile criteria cannot be directly quantified, they offer alternative descriptions of the acceptability of extreme events.

Best practice for integrated wastewater management

On the 24 November 1999, the Secretary of State for the Environment announced the extent of the environmental investment programme to be completed by the water companies by March 2005. Overall, in England and Wales, almost 3,600 km of rivers will be protected or improved and 3,500 unsatisfactory combined sewer overflows (CSOs) will be improved. This means an acceleration of the rate of the improvement of unsatisfactory intermittent discharges to an average of nearly 18 unsatisfactory discharges to be improved every week

Table 1 Fundamental intermittent standards for dissolved oxygen – concentration/duration thresholds not to be breached more frequently than shown (FWR, 1998)

a) Ecosystem suitable for sustainable salmonid fishery

Return period	Dissolved oxygen concentrations (mg/l)		
	1 hour	6 hours	24 hours
1 month	5.0	5.5	6.0
3 months	4.5	5.0	5.5
1 year	4.0	4.5	5.0

b) Ecosystem suitable for sustainable cyprinid fishery

Return period	Dissolved oxygen concentrations (mg/l)		
	1 hour	6 hours	24 hours
1 month	4.0	5.0	5.5
3 months	3.5	4.5	5.0
1 year	3.0	4.0	4.5

c) Marginal cyprinid fishery ecosystem

Return period	Dissolved oxygen concentrations (mg/l)		
	1 hour	6 hours	24 hours
1 month	3.0	3.5	4.0
3 months	2.5	3.0	3.5
1 year	2.0	2.5	3.0

Notes

1. These limits apply when the concurrent un-ionised ammonia (NH3-N) concentration is below 0.02 mg/l. The following correction factors apply at higher concurrent un-ionised ammonia concentrations:
   0.02–0.15 mg NH3N/l: correction factor = + (0.97 loge(mg NH3N/l) + 3.8) mg O/l
   >0.15 mg NH3N/l: correction factor = +2 mg O/l.
2. A correction factor of 3 mg O/l is added for salmonid spawning grounds.

Table 2 Fundamental intermittent standards for un-ionised ammonia – concentration/duration thresholds not to be breached more frequently than shown (FWR, 1998)

a) Ecosystem suitable for sustainable salmonid fishery

Return period	Un-ionised ammonia concentrations (mg NH3-N/l)		
	1 hour	6 hours	24 hours
1 month	0.065	0.025	0.018
3 months	0.095	0.035	0.025
1 year	0.105	0.040	0.030

b) Ecosystem suitable for sustainable cyprinid fishery

Return period	Un-ionised ammonia concentrations (mg NH3-N/l)		
	1 hour	6 hours	24 hours
1 month	0.150	0.075	0.030
3 months	0.225	0.125	0.050
1 year	0.250	0.150	0.065

c) Marginal cyprinid fishery ecosystem

Return period	Un-ionised ammonia concentrations (mg NH3-N/l)		
	1 hour	6 hours	24 hours
1 month	0.175	0.100	0.050
3 months	0.250	0.150	0.080
1 year	0.300	0.200	0.140

Notes

1. These limits apply when the concurrent dissolved oxygen concentration is above 5 mg/l. At lower concurrent dissolved oxygen concentrations the following correction factor applies:
   <5 mg/l DO, multiplicative correction factor = 0.0126 (mg DO/l)2.72
2. The standards also assume that the concurrent pH is greater than 7 and temperature is greater than 5°C. For lower pH and temperatures the following correction factors apply:
   pH <7, multiplicative correction factor = 0.0003(pH)4.17
   Temperature <5(C, multiplicative correction factor = 0.5

Table 3 99 Percentile values for RE classes (FWR, 1998)

Class	BOD (ATU) mg/l 99 percentile	Total Ammonia mg N/l 99 percentile	Un-ionised Ammonia mg N/l 99 percentile
RE1	5.0	0.6	0.04
RE2	9.0	1.5	0.04
RE3	14.0	3.0	0.04
RE4	19.0	6.0	
RE5	30.0	25.0	

over the 5 year period. Approximately 1,000 other intermittent discharges will also be improved e.g. overflows at pumping stations, storm tanks and at the sewage treatment plants.

The Environment Agency in England and Wales has a responsibility to maintain and improve the quality of inland and coastal waters. In May 1996 the Agency adopted the UPM methodology contained in the first edition of the UPM Manual (DETR, 1997). The Agency firmly supports and expects the use of the UPM2 planning procedures for new applications for consents for CSOs and other intermittent wastewater discharges (Crabtree and Morris, 2000). The use of the UPM procedure will be directed at achieving relevant environmental quality targets defined by the Agency. The Agency expects that due regard will be taken of the cost effectiveness of proposed schemes and the development of long-term sustainable solutions. In situations where there are multiple discharges to receiving waters the Agency will expect sewerage undertakers to apply the UPM procedure to develop integrated wastewater upgrading schemes at an urban catchment level.

Choice of river quality standards

The Agency expects the use of the 99 percentile standards or FIS criteria identified in UPM2. It has reviewed and clarified its guidance on the choice of criteria and, hence, the form of planning; the appropriate modelling tools; and, the data collection needs. This guidance (Morris and Fraser, 2000) defines three levels, based on the significance of the discharge, and identifies the characteristics used to identify the significance of a particular discharge. The guidance aims to inform decisions on the minimum environmental criteria to be applied and the commensurate level of sophistication required for modelling to produce environmentally protective solutions for intermittent wet weather wastewater system discharges. However, this guidance does not preclude the use of alternative methods or models where these can be shown to be equivalent.

The guidance shown below in Table 3 operates on the assumption that simple models will be applied to produce conservative solutions and sewerage undertakers will wish to employ more sophisticated modelling in the likely event that a more cost effective solution can be found. The Agency will accept more cost effective solutions provided there is no risk of deterioration in river quality and the additional cost of a conservative solution outweighs any risk of failing to achieve the River Quality Objective. In all cases, the Agency will require the discharger to demonstrate that the proposed scheme will allow the RQO standards to be met. Where FIS are not used, the discharger must demonstrate that the proposed scheme will allow the designated RE class 99 percentile river quality standards to be met. Where FIS are used, the minimum environmental standards for freshwater ecosystems will be those to achieve an ecosystem suitable for a sustainable Cyprinid Fishery. The FIS for a sustainable Salmonid Fishery ecosystem will only be applied to discharges affecting designated Salmonid Fisheries and salmonid spawning grounds.

Table 4 identifies a practical 3 tier approach to designing upgrading schemes on the basis of the significance of the discharge or group of discharges in relation to sewer system and receiving water characteristics. Each level has an appropriate minimum environmental criteria and associated minimum level of planning and commensurate modelling tools.

Conclusions – looking to the future

The concept of Urban Pollution Management has been available to the water industry of the UK for some six years. The major principles upon which UPM is founded have not changed in that time, suggesting that it is soundly based. Recent updates of the UPM Manual have resulted in the provision of improved technical guidance. UPM 2 presents a menu of environmental standards and practical application procedures. Environment Agency policy strongly supports the use of UPM 2 and will determine which standards and, consequently modelling approaches, are selected from the menu for a particular site.

The announcement of the National Environment Programme will finally enable the legacy of inadequate sewerage networks to be overcome. The implementation will require considerable efforts by the water companies in scoping, planning and constructing the new infrastructure. The Environment Agency is committed to ensuring that the programme will achieve these environmental targets in a consistent and timely manner. The use of UPM will underpin the planning effort and decision making that is required to enable the full environmental benefits of the water industry investment to be achieved.

It is likely that new environmental criteria may need be established by the requirements of the Water Framework Directive. Undoubtedly new planning and evaluation tools will

Table 4 Environment agency policy for choice of river quality standards for controlling wet weather discharges (Morris and Fraser, 2000)

A. LOW SIGNIFICANCE DISCHARGES

Dilution greater than 8.1 (foul DWF @ 5% low river flows), and there is no interaction with other discharges

The Agency will accept minimum data methods (e.g. simple mass balance calculations) for low significance discharges. Minimum pass forward flow at CSOs based on Formula A will be adequate for the majority of cases meeting the above criteria. This assumes that available dilution will be sufficient to protect the RQO. Where an environmental problem is known more detailed modelling may be required.

B. MEDIUM SIGNIFICANCE DISCHARGES

Dilution less than 8:1, and there is no interaction or limited interaction with other discharges, and the population equivalent is less than 10,000, and Cyprinid Fishery

Where all the above criteria apply, the Agency will accept the demonstration of compliance with the 99 percentile river quality standards for the designated RE class. Simple stochastic river impact modelling, applied in association with sewer hydraulic models, should be adequate for the majority of medium significance discharges.

Companies may wish to use FIS if this is likely to result in a more cost-effective solution. This will be acceptable to the Agency provided that, where there is a risk of deterioration in river quality, the sewerage undertaker can demonstrate that the proposed scheme allows the appropriate 99 percentile RE class standards to be met. In all other cases, it will be sufficient to demonstrate that the proposed scheme will achieve the relevant 90 (or 10) and 95 percentile RE class standards and that the cost of meeting the 99 percentile RE class standards is disproportionate to the benefit of meeting the 99 percentiles.

C. HIGH SIGNIFICANCE DISCHARGES

Dilution is less than 2:1, and Interaction with other discharges, and population equivalent is greater than 10,000, and Cyprinid or Salmonid Fishery

Where all the above criteria apply, the Agency will accept the demonstration of compliance with appropriate FIS. Detailed flow and quality modelling should be applied to appropriate wastewater systems and receiving water components to generate river quality results for comparison with the FIS. For FIS schemes that improve river quality, it will be sufficient to demonstrate that the proposed scheme will achieve the relevant 90 (or 10) and 95 percentile RE class standards and that the cost of meeting the 99 percentile RE class standards is disproportionate to the benefit of meeting the 99 percentiles.

Where there is a risk of deterioration in river quality, FIS solutions will only be acceptable provided that the sewerage undertaker can demonstrate that the proposed scheme allows the relevant RE class 99 percentile river quality standards to be met.

In all cases where FIS are not used, the sewerage undertaker must demonstrate that the appropriate RE class 99 percentile standards will be met.

be required, as the proposed Water Framework Directive will represent an overhaul of the existing aquatic environmental management regime. The Directive's main provisions, particularly the concept of river basin planning, and public consultation, fits well with the way in which the UK currently manages the water environment and the use of modelling tools such as UPM. The emphasis on ecological, rather than chemical quality, marks a change in approach, but reflects the emphasis of achieving demonstrable water quality improvements towards which the Agency has already moved. Beyond the UK, evidence suggests a gradual move away from fixed emission based criteria for CSO performance. The integrated wastewater and receiving water management approach, as identified in the UPM Manual, is being taken up in some other countries, where the wet weather impact criteria are recognised as being appropriate (Crabtree, 2000).

Currently, the practical application of the 3 tier approach to environmental regulation of urban wet weather discharges that underpins the Environment Agency's policy is focused on passive wastewater systems. A challenge for the future will be the uptake of this best practice approach to the regulation of actively controlled systems. These are now seen as a means of optimising integrated wastewater system performance and reducing costs, but will force environmental regulators to adopt a risk based approach to the regulation process.

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