Spending Wisely Through Environmental Design Optimisation

ABSTRACT

Methods of obtaining compliance with environmental standards are discussed, in relation to the assessment and design of effluent and stormwater discharges into the riverine and marine environment. The discussion compares the use of prescriptive (spill criteria) based solutions and solutions based on the assimilative capacity of the environment (which use predictive techniques such as numerical models).

Environmental solutions based on the assimilative capacity of the receiving water are identified as a means of delivering compliance with the standards, whilst focussing the right level of investment on identified assets. Environmentally focussed, predictive studies are discussed as a means of achieving these goals, together with the level of detail, data requirements, and the scenarios to be studied.

Case studies are presented, the principal example being taken from the implementation of a major study in Wales to deliver design solutions and compliance with the Environment Agency's Shellfish Waters Policy.

A practical means of delivering effective environmental studies, Environmental Design Optimisation (EDO™) is introduced.

EDO is an environmental quality solution designed to provide:

1. a better understanding of the impact of discharges
2. a more efficient means of designing mitigation solutions for environmental compliance
3. a better use of valuable network model assets
4. significant capital and operational savings through environmental targeting
5. Detailed modelling analysis within sensible project timescales

EDO has been verified through post scheme evaluation.

BACKGROUND

There are numerous examples in UK environmental legislation and policy that allow two options for the attainment of water quality objectives. The two well known pieces of legislation (certainly within the context of AMP3) are the Bathing Waters and Shellfish Waters Directives, expressed as Regulations and Policies within the UK. These two options can be considered as:

1. PRESCRIPTIVE: Engineer a solution to an end of pipe quality standard
2. ENVIRONMENTAL QUALITY: Design to a water quality standard that takes into account the environment into which the discharge is being made (the receiving environment)

Both approaches ultimately aim to achieve an environmental objective. With a prescriptive approach an end of pipe standard must be set to achieve the water quality objective, generally based on a statistical analysis. In deriving the end of pipe standard, the regulator must take account of the discharge impact in the general rather than the specific case. For example, the amount of dispersion available is not considered.

To ensure protection of the environmental quality and the attainment of the environmental objective the end of pipe standards are generally set with some conservatism built in (i.e. reasonable worst case). Therefore, if the receiving environment is by its nature able to cope with the wastewater discharge, for example it is highly dispersive, you run the risk of over-design. In addition, decisions must be taken on which assets to target. Generally and understandably, this is historically Ly based upon the biggest and closest assets, which may not be the biggest problems.

The prescriptive approach is well understood and, in many cases, has resulted in schemes that work. However, that will not always be the case, either because 'other' contributing pollution sources compromise compliance, or because engineering constraints do not allow a full prescriptive solution implementation.

The other option (environmental quality) provides both operators and regulators with a far greater understanding of the receiving environment and its assimilative capacity. This understanding facilitates the identification of the key pollution sources and the targeting of investment to assets to give a significant environmental return against the required water quality objective. In doing so it is distinguished from simpler approaches, such as SIMPOL, where the focus is on the assets and solutions rather than the environment.

To understand the environment and the impact of discharges upon it we need to know:-

- How local watercourse hydrodynamics work;
- How much of the pollutant is discharged into the environment;
- How the pollutant behaves in the environment; and
- How this knowledge translates into compliance with policies and standards.

At its core the environmental quality option requires a representation of the environment, ranging from a simple box model to a complex three dimensional hydrodynamic and water quality model. Whatever the complexity of the model, environmental factors such as bathymetry, tides, river flows and winds must be taken into account. To provide this level of understanding there are many other component parts to most 'quality' studies such as environmental surveys, telemetry and monitoring data and network modelling.

It can be seen that the integration of all this information and the integration of multiple sources (which can involve several continuous discharges, many intermittent discharges and background sources from rivers) will be highly complex. Couple this with the fact that the impacts need to be understood under many different rainfall conditions and, in the case of coastal studies, the stage in the tide that discharges

occur, then there are many thousands of different scenarios that need to be accounted for to obtain a full understanding of compliance.

The handling of so much data, and so many scenarios, using traditional methodologies for predictive studies, would be prohibitive in terms of time and budget.

THE EDO APPROACH

There are many generic methods used when designing studies using the 'environmental quality' option, broadly split between the coastal and riverine environments. These are centred on mathematical models, which have been in use for some time, and their general use is well understood.

Environmental Design Optimisation (EDO™) takes this to a higher level, through the use of additional software and analysis techniques, to produce assessments with thousands of permutations and the ability to quickly re-assess if engineering parameters change. EDO therefore allows the fulfilment of the data requirements and scenario assessments identified previously.

This allows very detailed assessment within sensible project timescales; be these weeks, months or years. Using EDO will also provide the possibility for more accuracy and therefore scope for more precise and refined engineering solutions, such as storage volumes and UV doses. For example, EDO aims to represent reality by evaluating many environmental scenarios. Figure 1 presents a simulated annual timeseries of faecal coliform concentrations at a shellfish harvesting area under one scenario. The faecal coliform concentration is driven by all continuous and intermittent discharge and diffuse pollution sources. Variations in diffuse pollution, WwTW final effluent flow and bacteriological decay are estimated in the time-series. By calculating the period of time that the concentration exceeds the faecal coliform concentration threshold and undertaking statistical analysis over a number of years, and many scenarios, it is possible to compare directly to percentile standards. To do this using models directly would be near impossible due to the run time required.

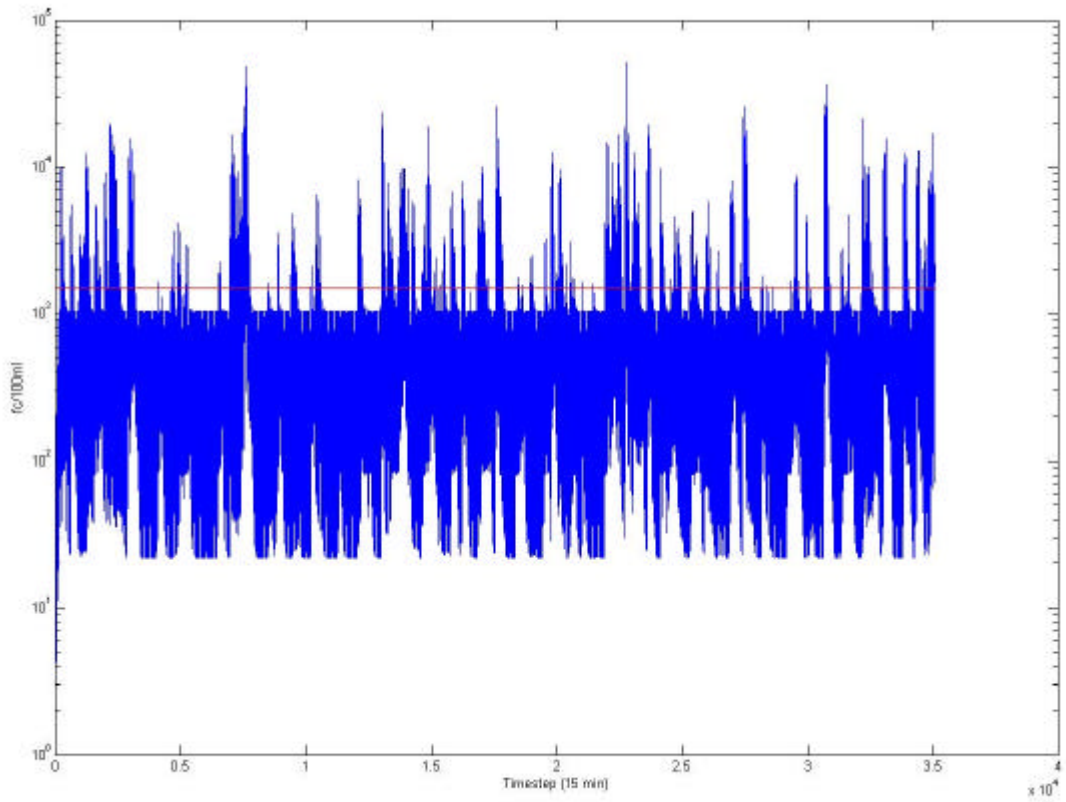

Figure 1: Example simulated annual time series of pollutant concentration

By reducing the conservatism in the calculations, solutions can be designed that call for less capital expenditure, and also tertiary treatment options, initially identified as part of an obligation to improve quality, may in fact not be required to deliver compliance. This means that both capital and operational efficiency is improved.

On the face of it, delivering 'less engineering', be this in terms of reduced storage volumes or removing the need for tertiary treatment, may seem to raise the risk of non-compliance. However, the improved understanding of the local environment and the fate of pollutants, together with improved investment targeting means that risk is better understood and better managed, and not increased.

As mentioned, EDO allows diffuse and other pollutant sources to be investigated and amalgamated with impact from wastewater discharges. Diffuse pollution has become the most significant outstanding obstacle to further improvement in water quality (Ministerial Guidance, DEFRA, 2004) and the environmental regulator is charged with confronting the issue. The water industry can support the regulator and avoid unnecessary investment by investigating diffuse sources as part of the EDO assessment. Of course, this does not mean that diffuse pollution is the responsibility of the water companies and this subject has been debated at length with the environmental regulator in many cases.

The Environment Agency's guidance document, Water Quality Consenting Guidance for Defining Quality Outputs for the PR04 Environment Programme under the Shellfish Waters Directive (EA, 2003), explains that the Water Company is only

asked to investigate its assets and that other potential sources, such as diffuse pollution, are the responsibility of the Agency to investigate. However, it states that, 'it would be advantageous to co-ordinate the investigation work of the Agency and Water Company'.

It is important to realise that EDO will not always lead to less storage or less treatment for a particular scheme. The increased understanding of the environment may lead to the conclusion that neither of the options (prescriptive or quality) will deliver the environmental objective (for example, in an area of multiple discharges). In the extreme case it may demonstrate that it is not possible to meet the environmental objective through sewerage network improvement alone, possibly due to diffuse pollution breaching a water quality standard before any point source discharges are considered. This scenario, of course, could not be foreseen without environmental modelling, and therefore there may well be a shortfall in environmental performance when compared to expectation.

In numerous areas of the UK we have found that a higher prescriptive capital spend can deliver less environmental benefit than a lower EDO capital spend if the former is not environmentally targeted. Taking the Milford Haven Shellfish Water, in south Wales, as an example, under the AMP3 business plan the key improvements within the Milford Haven were UV and ten spills at the WwTW in Milford Haven town and Pembroke Dock. This seems a reasonable approach given the size of these WwTW. However, both of these WwTW discharge into deeper water in the downstream half of the Haven. The greater dispersion/dilution in this area means that the predicted impact on the shellfish water is relatively low compared to WwTWs discharging further upstream. Under the AMP3 Dwr Cymru Welsh Water (DCWW) Shellfish Strategy, funds have been redirected from Milford Haven and Pembroke Dock to Merlins Bridge and Burton Ferry, resulting in a greater environmental cost-benefit. Figure 2 demonstrates the reduction in faecal coliform concentration from continuous discharges pre and post investigation (the investigation formed part of the Prioritised Development Plan, or PDP, the implementation strategy used for DCWW).

Current **PDP**

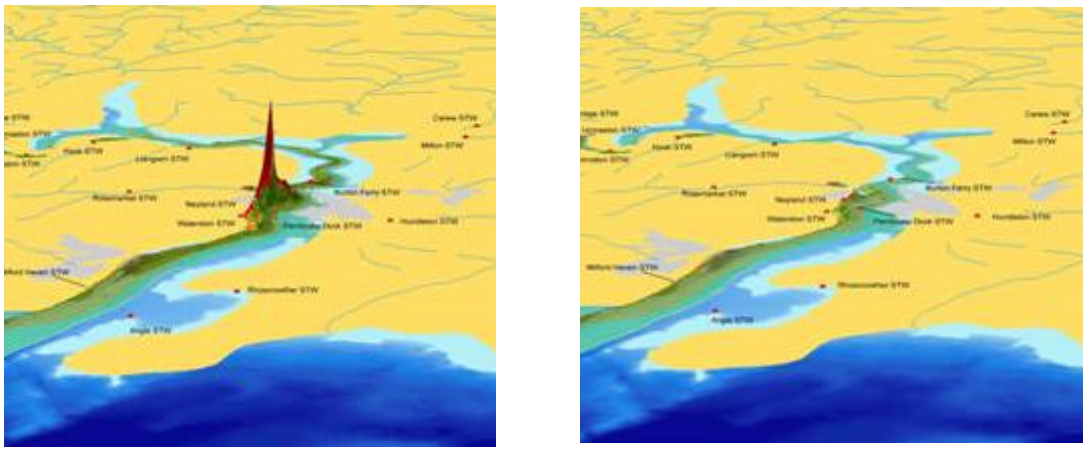

Figure 2: Estimated faecal coliform concentrations pre and post PDP

Often the redirected investment can be used on more schemes, more solutions and an improved environment programme for no additional budget. In these cases EDO has

be used to prioritise investment while focusing on meeting the environmental objective.

Furthermore, many additional factors can influence a capital improvement scheme. These include existing environmental quality, cost, importance and value of receiving water and, if we are honest, politics. All of these can be incorporated into the EDO process.

A prime example, of this is the DCWW AMP3 Prioritised Development Plan (PDP) mentioned above. DCWW is very keen to ensure that the AMP3 Shellfish Strategy budget is spent to provide maximum benefit to the environment.

A high resolution water quality modelling system was built for the Welsh coastline as the core to the assessments. Importantly the models had to include all known sources of bacteria where feasible. EDO was used to evaluate compliance throughout the Shellfish Waters. Where standards were not met the modelling results were analysed to highlight the key continuous and intermittent discharges impacting on the Shellfish Water and in particular the specific Shellfish Harvesting Areas. Once the current water quality situation was understood the environmental benefit of many different asset improvements were assessed and the PDP was produced.

As is always the case, the benefits of the environmental quality option come with some cost. An environmental quality approach requires more time and an investment from the water company. To ensure that the studies can be comprehensive and sufficient time is allowed for engineering schemes to be designed and completed if required, environmental quality assessment should be integrated into the project from the initial planning phase.

REGULATOR

In both England & Wales, and Scotland, the Regulator has seen the advantages of the EDO process.

Although there can be resistance at first, the greater understanding of the local impacts, the understanding of the fate of pollutants and the flexibility of the studies (in that many different scenarios and sensitivities can be tested) has resulted in the environmental regulator approving of EDO and, in several cases, recommending its application.

EDO was first applied to an intermittent discharge design for the Tayside Private Finance initiative (PFI) (Dundee and environs sewerage improvements). SEPA were very receptive to the EDO process and recommended its application to subsequent PFI schemes.

As much as is possible, the environmental regulator is included as part of the project team, from the planning phase through to sign off, in order that models, methodologies, field data and parameters are approved and accepted by all parties. It would be untrue to claim that this is always an easy process and intensive debate with the environmental regulator has formed part of the development of the EDO process.

This has two advantages; firstly, the results are more robust and secondly, future applications of EDO are likely to be approved due to the environmental regulator's knowledge of, and involvement in, the methodology.

OVERVIEW OF AMP3 APPLICATIONS

Within AMP3, the environmental quality option, has been used for bathing waters and shellfish water investigations in the coastal zone and riverine system assessments further inland. These examples have been taken from studies that Metoc has undertaken, and so these studies have employed the EDO interpretation of the 'environmental quality' option.

1. EDO has been used to evaluate scheme design and environmental compliance for various bathing water and shellfish schemes in England, Scotland and Wales. Alternative design solutions have been recommended, which often are significantly more efficient than 'baseline', prescriptive spill criteria solutions.
2. EDO was used to investigate the merits of implementing an upper tier consent to a river discharge thought to impact downstream fisheries. The process identified that the necessary environmental protection was being delivered under the existing consent. This study was undertaken to support a case presented at a Public Hearing.
3. The Sunderland public enquiry used EDO to demonstrate the environmental performance of discharges under objection and identify other discharges responsible for aesthetic pollution on beaches.
4. EDO has also been used to determine the impact of intermittent and continuous discharges on a number of rivers and watercourses in England. The EDO approach allowed an understanding of the environmental fate of the discharges, and therefore any storage/attenuation requirements were optimised to reflect environmental need. In some circumstances, the local environment had unusual characteristics, in that discharges were to drains which had flow characteristics which were bidirectional, or static for significant periods. EDO tools were custom built to reflect this requirement.
5. Studies associated with tertiary treatment under the UWWTD have been undertaken. The Agency had identified a number of works requiring nutrient stripping: subjecting the Agency studies to EDO techniques showed that in a number of cases the installation of tertiary treatment would have no impact on the trophic status of the watercourses in question. This would have led to the investment of capital and operational expenditure, nominally for environmental benefit, which would have had no impact on environmental improvement.
6. EDO has been used to integrate waste water and drinking water studies. The release of waste water effluent and the implications to an abstraction point were assessed and control strategies designed to minimise risks to the abstraction point. This application has uses within the wider context of the Water Framework Directive.

POST SCHEME EVALUATION

The only real test of an investment scheme is post commission monitoring. Examples of EDO being used and requirements being met are studies conducted for Anglian Region Bathing Waters. Many of the discharges implicated in Bathing Water compliance in the Anglian Region have been subjected to EDO (both for continuous and intermittent discharges, during both AMP2 and AMP3). Where EDO was employed, solutions significantly more efficient than the comparable 'spill criteria' solution were implemented. Anglian Region's compliance with both the Guideline and Mandatory standards of the Bathing Waters Directive has been excellent.

In addition, in some investigations in the Anglian Region, the implementation of the 'environmental quality' option, in conjunction with the use of available network models, led to the identification of critical issues in some sewerage networks, which otherwise would not have been dealt with.

The methods can also be used for forensic studies if failures do arise. These studies can help to exclude water company assets from blame, or can be used to identify network issues which were not necessarily well understood until they were analysed in detail. This type of forensic study requires the use of network model data, telemetry data, and meteorological data, but can be very informative. Studies for an English water company have helped to exclude company asset's from blame for failures, and have also helped to identify operational issues which have been subsequently dealt with.

SUSTAINABILITY

'Sustainable development is key' is the first Key Message of the Secretary of States Principal Guidance on PR04.

Sustainability can and has been addressed through EDO. The concepts of environmental modelling and sustainability indices such as '*ecological footprinting*' have already been combined in an EDO report for a proposed appropriate treatment solution for a coastal discharge in England. Environmental impact of a preliminary treated discharged were analysed, and reported together with a study on the *ecological footprint* of a higher treatment level.

[note: *the ecological footprint is an estimation of the ecological impact of a given process or activity by estimating the carbon dioxide output (expressed as the area required to sequester the discharged CO_2), and comparing it to the area that is estimated to be available to each individual on the planet. An indication is gained as to the ecological impact (or lack of impact) of a given activity*]

Sustainability issues will become increasingly important in the overall evaluation of the environmental benefit of any scheme which purports to provide environmental benefit.

AMP4 APPLICATIONS (AND BEYOND)

Ministerial guidance in both England and Wales for AMP4 has limited the funding available for improvements to assets on environmental grounds, particularly in the coastal zone. In Wales, the National Assembly ministerial guidance on Periodic Review 2004 (PR04) clearly states the requirement to demonstrate that solutions are cost-effective through scheme-based appraisal. They will only go ahead on the basis that the outcomes including wider benefits justify the costs. While this position is not clearly stated in Ministerial Guidance for England a similar message is put across. As a result the prescriptive approach cannot necessarily be applied in a blanket fashion but instead only to those assets that are shown to have an impact.

This small but significant shift in approach means that many improvement schemes that would be required under a prescriptive approach will either undergo only a feasibility study in AMP4 with a view to the capital scheme taking place in AMP5, if required, or they have been removed from business plans altogether. DCWW have used the PDP tools and techniques to inform their recommendations on shellfish schemes in AMP4.

A different approach is therefore required by both the Regulator and the water company and this is demonstrated by the use of Regulatory Impact Assessment to inform the final guidance on PR04. It is an opportunity for them to work together to ensure that necessary improvements are completed. In some cases they could join forces in seeking funding from OFWAT to complete such schemes. It is understood that many in the industry believe that an EDO type approach should form the basis of any feasibility study or investigation to understand all impacts on the receiving environment even if the focus is on a single named asset.

The Water Framework Directive, with its requirement for 'holistic' catchments analysis, is an area where the 'environmental quality option' will have a significant advantage. The ability to assess multiple discharges, diffuse sources, agricultural and urban sources, and to incorporate groundwater sources, will mean assessment will be complex. The integration of collected data and a wide variety of predictive techniques will be required to deliver studies, and consequently solutions.

The new Bathing Waters Directive, when (if) it is implemented, will require a much better understanding of the actual impact of discharges (and diffuse sources) on Bathing Waters. This type of approach may also lead to effective real-time management of Bathing Waters.

Climate change may have significant impact on current scheme designs. Changes to rainfall pattern and intensity may mean that today's 'spill criteria' solutions will not deliver. Climate change studies have already suggested that current prescriptive, spill frequency methods may not be appropriate .

Of course, there may be many other issues that would benefit from this approach, i.e. where can money be saved but compliance still maintained. It is a challenge to the industry to find such issues and implement better environmental solutions.

SUMMARY

The methods available to provide environmental compliance are considered.

The ‘environmental quality’ option is discussed in detail, particularly in terms of the data and scenario requirements needed for an understanding of potential impacts, and therefore solutions.

A methodology for the delivery of environmental quality solutions, Environmental Design Optimisation (EDO), is discussed, and implementation examples are provided.

An overview of future applications, both for AMP4 and beyond, is considered.