PAPER 11

River Sheaf and Don River River Impact Modelling - development of Hydro Works QSIM and MIKE II models to identify critical overflows in the catchment

by

Mark Bottomley of Montgomery Watson

RIVER IMPACT MODELLING - SHEAF AND DON RIVERS IN SHEFFIELD

Lessons Learnt from the Project Manager's Perspective

D.M.Bottomley. Principal Engineer Montgomery Watson

Introduction

This paper considers the experiences and lessons learnt from a river impact study on the Rivers Sheaf and Don in Sheffield. First the justification for the river impact study is considered and then the best method of achieving the objectives are considered. The paper then identifies some of the lessons learnt both from a technical and project management perspective and examines the outcome of the study.

The project was successful as its objective, which was to identify the overflows which could give the maximum reduction in impact on the river Sheaf and Don with the limited investment capital available, was achieved.

The paper is presented by Mark Bottomley of Montgomery Watson Ltd who acted as the Project Manager on the study. Contributions for the paper were supplied by Mr Peter Myerscough and Mr Ed Bramley of Yorkshire Water Services and from Mr Peter Bridgens of Design and Build Services, Sheffield.

River Sheaf and Don System

The river system considered is the River Sheaf, Porter Brook and the River Don. A number of smaller tributaries also flow into the River Sheaf. A total of 43 overflows spill in the River Sheaf and Porter Brook system and the system has a history of pollution problems. The Sheaf and Porter Brook have a confluence just upstream of a culvert which carries flows under Sheffield town centre and into the River Don. The rivers in the system have very mixed characteristics, and the spill volumes of CSO's vary widely across the overflows. The river system is shown on Fig. 1.

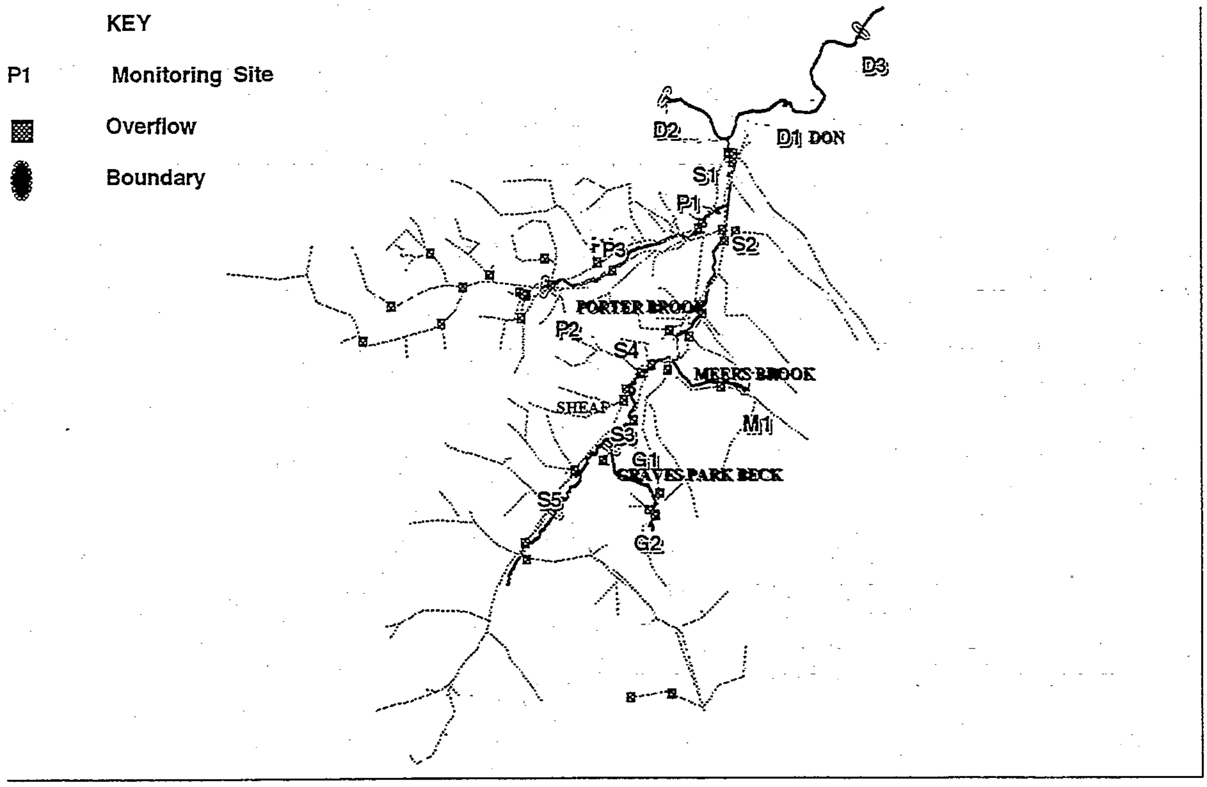
Key facts about the system are:

- Porter Brook and the River Sheaf are small rivers and very steep
- The River Don is much larger and slower.
- A number of weirs are present on the rivers.
- The largest spill volumes occur at the lower end of the catchment at Sylvester Gardens CSO. However the discharge at this point effectively goes straight into the River Don, as it passes through a culvert.
- A number of smaller CSO's spill at the top of the systems, where rivers are quite small.

The system is therefore complex and simplistic solutions which deal with overflow spills without considering the impact on the watercourse may lead to inadequate or very conservative outcomes.

Fig. 1 River Sheaf and Don Systems:

Plan showing data collection sites and boundaries of the system

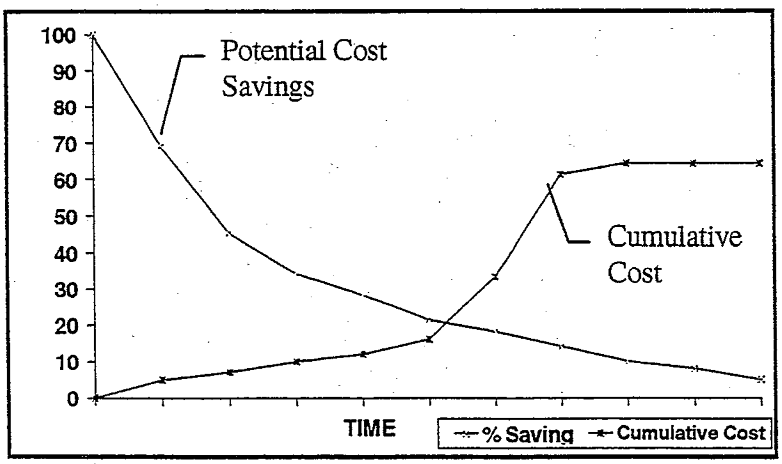


Why Do a Study?

In any project the most crucial part is to determine the objectives. As shown in the graph below, the greatest cost savings in projects are made at feasibility or outline design stage, but this requires clear definition of the objectives. Implementation of the solution to perceived pollution of the Sheaf and Don cannot begin until the problem is defined. The first requirement for this system is to determine which overflows are contributing the most significant impacts on the rivers. In line with nearly every Water Plc in the UK, YWS found themselves in the situation of having limited funding allocated for solving major problems. AMP2 estimates of the extent of the problems in the Sheaf Valley area led to an allocation of approximately £10M. As part of this study it was identified that using Formula A equivalent the cost of upgrading the overflows to the minimum, Formula A standard would cost at least £30M, and may

Need for Investment at Study Stage

As Most Appropiate Level of Investment Identified by Study Work



not have provided a solution at all overflows. Traditional solutions such as Formula A do not take into account the different characteristics of the drainage areas and receiving waters. This was pointed out 26 years ago in the Technical Committee on Storm Overflows and Disposal of Storm Sewage[1].

The budget for the total works within the catchment was effectively fixed. The purpose of this study was therefore to identify the most cost effective solutions that would provide the maximum benefit within the river system for the amount of money allocated in the budget.

The study therefore had a clear objective and had a fixed timescale to allow design to start. Mathematical modelling of sewer systems has received a bad reputation in some places because of a lack of clear objectives of the study and a failure to differentiate between research and project activity. The credibility of a process depends as much on its correct application in the marketplace as it does to its technical merits.

Identification of the Methodology

The initial decision as part of the project was to determine what level of study should be carried out. On a project of this type the alternative types of study that can be carried out can be simplistically defined as:

- Volumetric analysis using hydraulic model or Formula A calculations.;
- Simple mass balance analysis using total river volume and hydraulic model with default parameters; and
- Detailed river model.

The cost implications of these three types of study vary widely. In the case of the River Sheaf the volumetric analysis had been carried out previously for large parts of the catchment as part of drainage area studies. This identified some major overflow spills, in particular at Sylvester Gardens near to the confluence of Porter Brook and the River Sheaf. Simple mass balance assessment had not been carried out previously and remained an option. However, observation of the catchment shows that there are large numbers of overflows which are clustered in groups and there are other overflows which are scattered more widely across the catchment. The initial decision was made that simple mass balance approach would not identify the critical reach on the river and would not necessarily identify whether improvements at the top of the catchment would equal or even exceed improvements caused by upgrading the larger overflows towards the bottom end of the catchment near to the River Don.

It was decided therefore to proceed with a full river impact study. This decision was reached because it is evident from looking at the critical path for a mass balance type (see programme below) approach that if a decision was made that the mass balance approach would be undertaken and it was later found to be unsatisfactory or given an inadequate level of detail

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1 Standing Technical Committee on Storm Overflows and Disposal of Storm Drainage. Final Report (1970) HMSO London

then commissioning a river model at a later stage in the study would not allow the study to be completed within the required timescale. This is a critical point to be considered when carrying out river impact studies. Data collection on the river is a time consuming process and if the data collection operation is not carried out early then delays will inevitably result.

Therefore, at the end of 1995, it was agreed that a full river impact study would be carried out for the River Sheaf, Porter Brook and parts of the River Don. It was agreed that Mike 11 would be used as the river model and that data collection would be carried out for the river both for flow and quality. A summary of the extent of the data collection is given below in Table 1 At the same time some additional flow monitoring on the sewer network was carried out. This was part of an ongoing project to confirm the hydraulic performance of parts of the River Sheaf catchment.

Table 1 Extent of River Data Collection

Equipment Type	Determinands Measured	N° Of Units
SONDE (Continuous Data Logger)	Dissolved Oxygen Temperature PH Depth	12
EPIC SAMPLER (spot sample collecter)	Laboratory analysis for: BOD NH_3 Nitrate Suspended Solids	11
EA gauging station	Flow Data	2

The river modelling for Urban Pollution Management studies is a new technology and as any project management text will say new or innovative projects are generally only carried out with full awareness of the risks involved. An essential part of this project therefore is the attempt to quantify both in the magnitude and extent of impact the risks involved in carrying out the study and then, as far as possible, to plan the study in a way to alleviate these risks.

Risks Involved in the Study and Measures to Alleviate Risks

The risks involved in this type of study can be stated to be as follows:

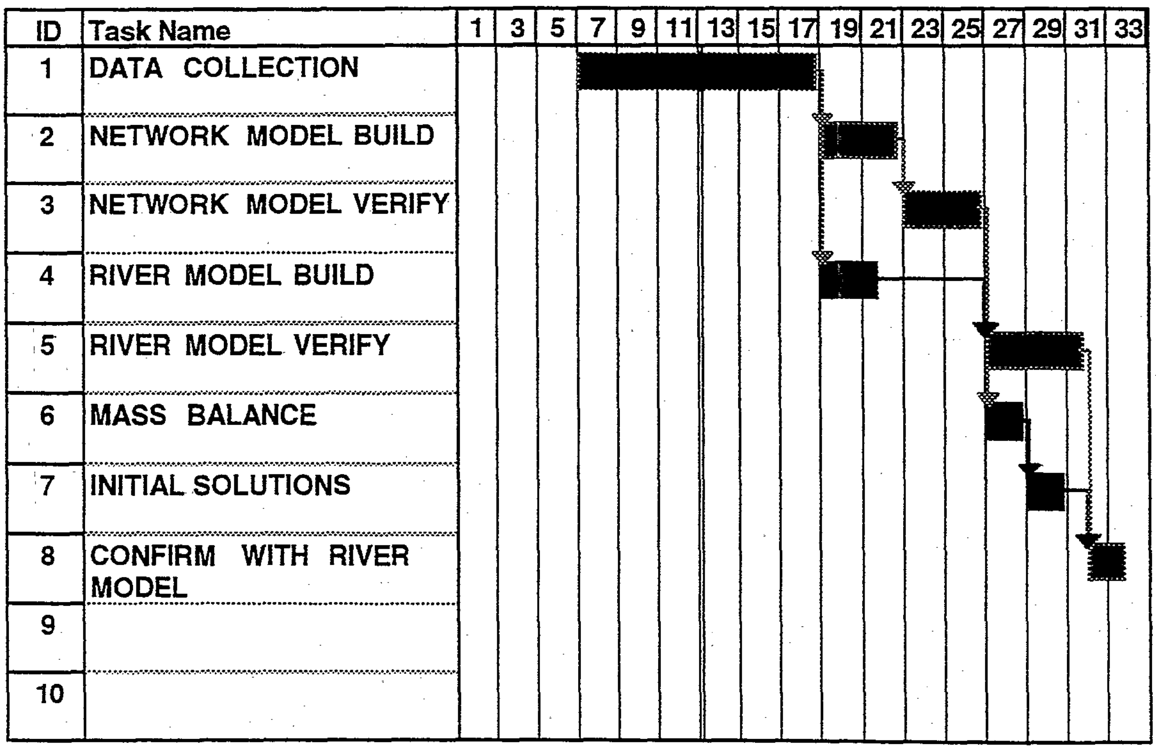
- Risk that the objective of the study is not achieved. This risk would occur if the Environmental Agency would not or could not accept the outcome of the study.
- The objective of the study is not achieved within the timescale to allow construction prior to the end of 1999. If this occurred YWS would fail to achieve the levels of service required.
- Cost of the study exceeds benefits. In this case the risk is that the total cost expended to achieve the outcome is less than the net benefit of the study. This risk requires that costs are identified in advance and the likely benefits are quantified.

On this study the risks were considered and ameliorated as far as possible by the set up of the Project Team and the sequence of work.

The most significant risk in terms of effect, though not necessarily in terms of likelihood of occurrence is that the Environment Agency would not accept the outcome of the study. In terms of the capital programme even a request for more information could effectively delay the whole project and effect the outcome. A decision was made at the start of the project to include the Environment Agency in all discussions concerning the technical development of the project. The Environment Agency attended the team's meetings from commencement and they were fully informed of the positioning of data collection equipment, the type of rainfall events that were collected, the progress on the study and also any technical problems that had developed. Local EA. representatives were also involved to agree amenity classifications.

The sequence of work on a study of this type is critical as an interruption in the progress of any particular work item can hold up the study. The critical path on the study will show that any individual items can become critical if the delay on one point or task exceeds what is quite a small delay. The critical path is shown very simplistically on the diagram attached. For the river model to be successfully calibrated and verified it is imperative that the inputs to the river model are established. This requires that the wastewater network model and a wastewater treatment work model, if applicable, are completed, calibrated and verified prior to any

CRITICAL PATH FOR RIVER MODELS

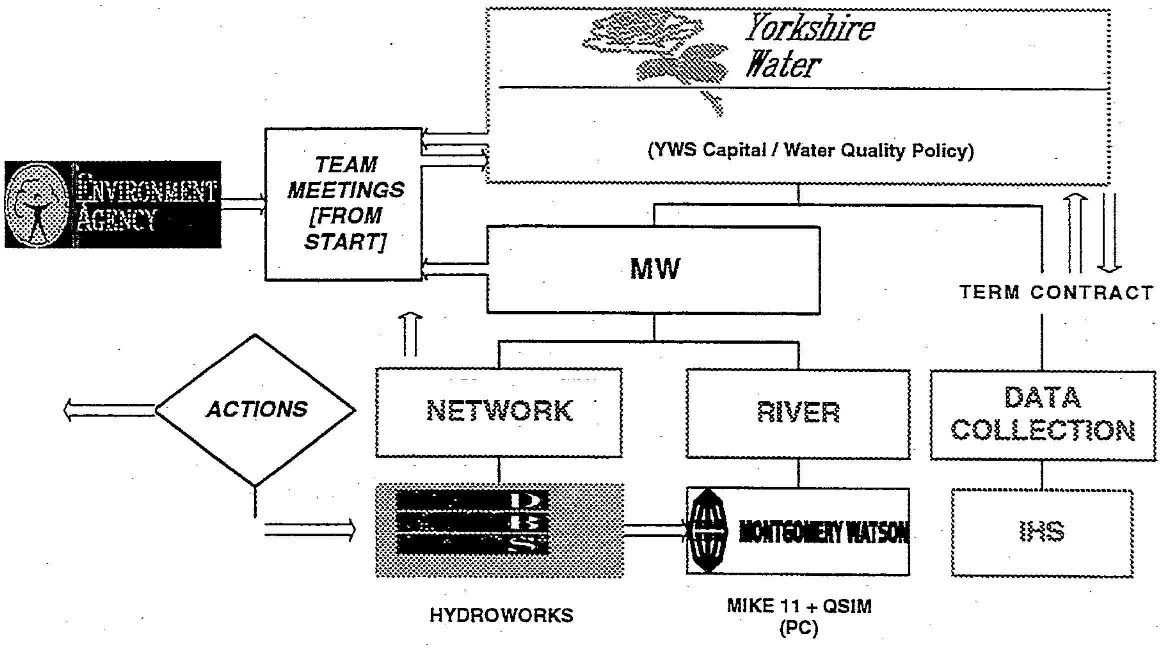


attempt to calibrate the river model for storm events. It is essential that the Environment Agency are in agreement with the calibration or verification of the network or the wastewater treatment works model. Because of the potential number of critical paths on the study, which may run through data collection in the network or river and through model build in the network or river, it is important that the sequence of working is well thought out. In order to reduce the risk of delays on the project the project team was also considered carefully.

The network modelling was carried out in parallel to the river modelling and different terms were used for each. Sheffield Design & Build Services were used to construct the network model and verify it for hydraulics. The river modelling was carried out by Montgomery Watson Ltd. Data collection was carried out by Integrated Hydro Surveys. The Project Team was project managed by Montgomery Watson Ltd reporting to Yorkshire Water. This Project Team structure allowed elements of the project to run in parallel but with clear and unambiguous responsibilities. The project team is shown below.

Another risk which could have affected the project is the risk of unforeseen events causing problems in the project. This risk was reduced by ensuring that there were local agencies involved in the work. Sheffield DBS are the agency for operation and maintenance of the sewerage system and therefore they have local knowledge. The local representatives from the

SHEAF VALLEY PROJECT TEAM



Environment Agency were also invited to attend the project meetings, and they had valuable input to the study at these stages.

In any innovative project there is a high risk of failure because by definition untried and untested methodologies are in use. Although river models have been in existence for a number of years their use for measuring intermittent discharges is new and is comparatively untried. The data collection to allow the calibration and verification of the models is also new technology and feedback on how to carry out these studies was very limited at the beginning of the study. The risk of problems in the technology used was therefore high. This was the most difficult risk to manage and the only practical way of managing this risk was to ensure good communication between all members of the team so that any problems or difficulties could be discussed and understood as soon as possible.

The final risk is climate. This is a fundamental risk, i.e. one outside the control of the project team. Although the effects of climate, i.e. no rainfall can be minimised by good planning, in this type of study the Project Team are literally at the mercy of the elements. The only exercise that the Project Team can do to reduce the risk of climatic effects causing delays is to ensure that wherever possible the maximum float is given on the data collection activities. It is essential therefore that maximum effort is carried out at the beginning of the study to ensure that the data collection equipment is installed as early as possible, and concurrently. Seasonal variations in flow and quality must also be considered.

Lessons Learned from Sheaf Valley Study

As expected on any study of this type some delays and problems were encountered. In particular, the anticipated risks of problems with climate did occur, and also some problems with the use of the model.

Climate

Problems were experienced with too much precipitation in the form of snow, and too little precipitation in the form of rain. The river survey went into the ground in January and although some good rainfall events occurred early on in the flow survey period these were rendered useless because of snow on the ground. Ideally, the river quality survey should have commenced later, but a decision was made to progress with this activity to help progress the study. In the event it may have been better to delay installation of survey for two months.

Vandalism was also a problem. The river quality monitoring sites were fully enclosed, the structures mounted by the flow survey contractor on the edge of the river. Despite this, vandalism was a problem and some equipment was damaged.

The final date for completion of all survey work was 6 June 1996. This left very little time to complete the verification of the river model in order to provide outline solutions at the end of September. In order to progress the study and avoid moving the completion date it was decided to carry out an initial mass balance assessment using the output from the verified and calibrated QSIM model of the sewer network. This work was carried out in parallel to the river modelling.

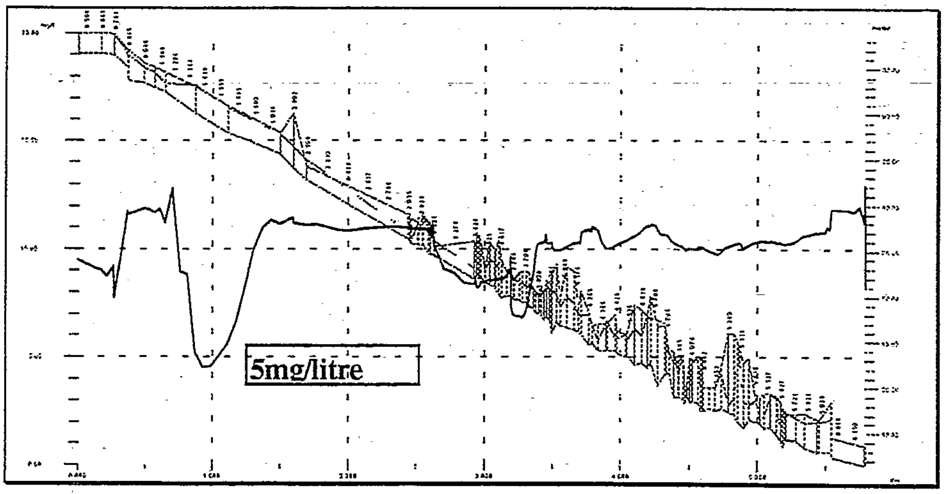
Software

The river characteristics at some locations caused a few problems with the use of Mike 11, in particular on Porter Brook. The reaeration constant equations for Mike 11 do not work well with low flows, below 600 mm. Reaeration constants were therefore fixed where flows below this level occur. This occurred in several places. Some other problems appeared to be caused by bugs in the software code. These were reported to the supplier DHI who reacted very promptly and as a result some patches were required for the software. These problems were not specific to the type of catchment. They caused significant delays in the programme until it was realised they were more than just verification problems. Once this was realised the model was calibrated within a few days.

Other problems that occurred with the model were due to the fact that parts of the river were steep and carried quite low flows. Depth warnings came up frequently and some cross-sections needed to be added or modified to ensure that reasonable depths could be maintained. In the event the team are confident that a workable tool was obtained even though they were working near to the limits of the software.

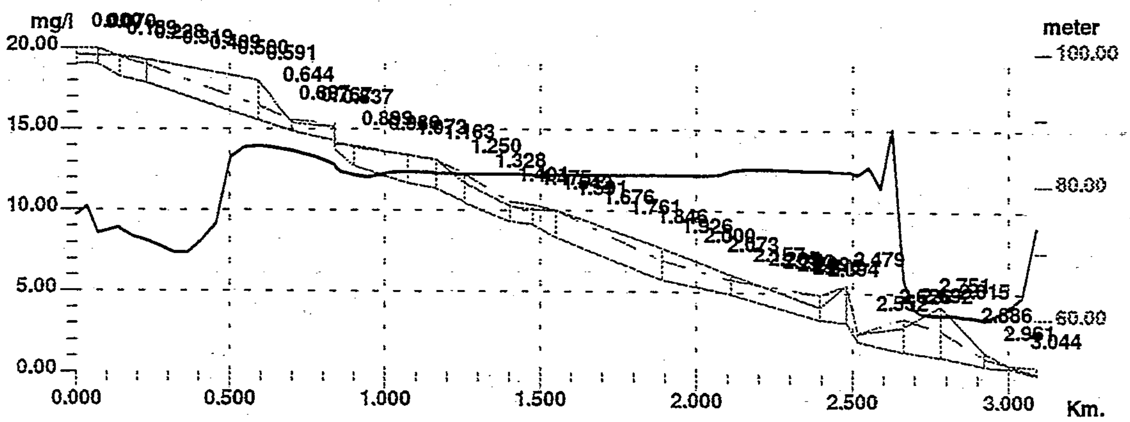
Performance of the Rivers

Millhouses DO SAG : Event N - 17/05/96



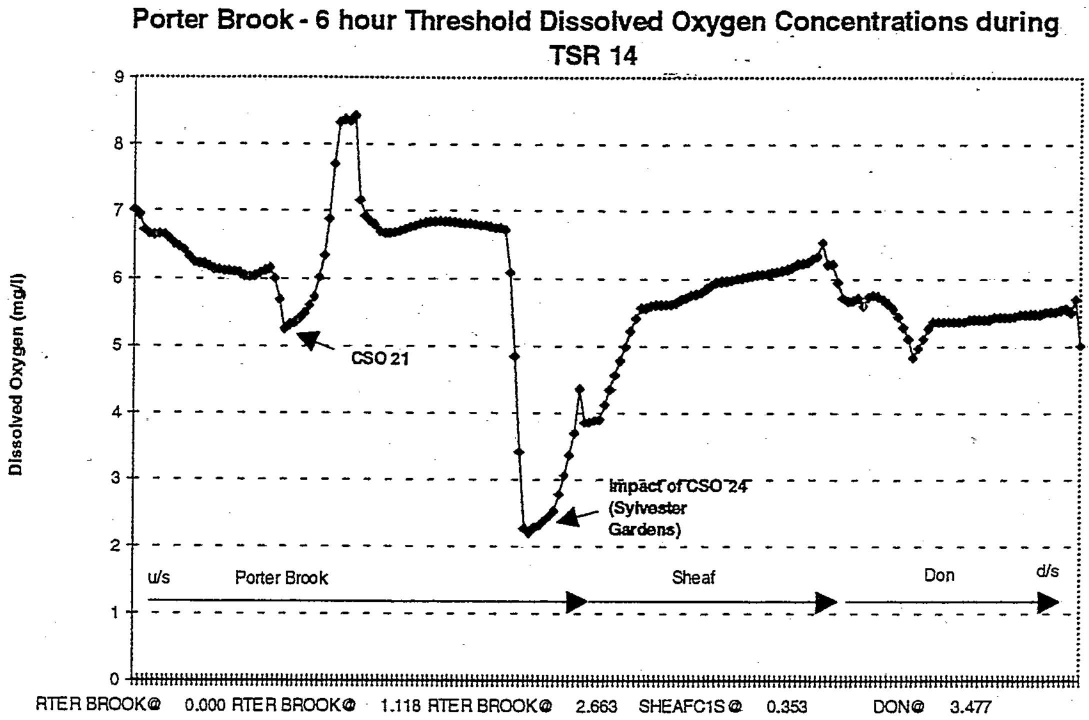
The plot on the left shows the significant DO sag where Millhouses group of CSOs meet the River Sheaf.
The Graph below shows the impact at Sylvester Gardens for the same event

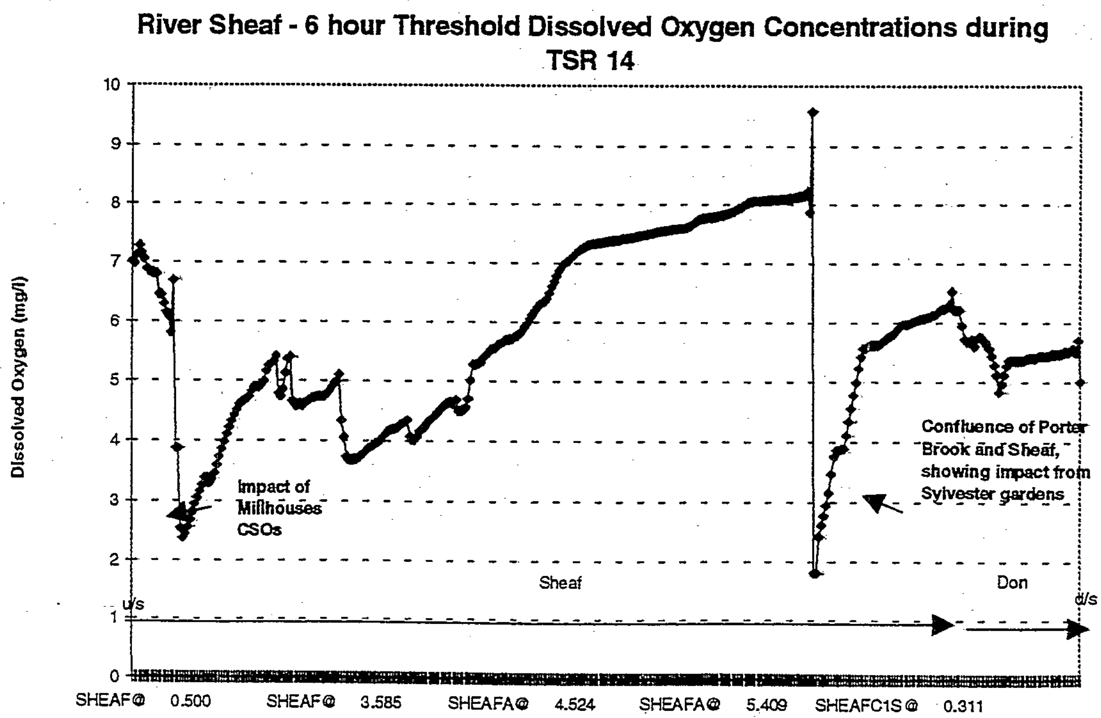
Sylvester Gardens & Upper Porter Brook DO SAGs : Event N - 17/05/96



Once the river model had been calibrated the model was re-run by removing the CSO impacts from critical events one by one and determining the resulting reduction on impact on the river by comparison with the baseline impacts. Once this was done the CSO's could be ranked in terms of impact on the river.

The relative size of the CSO impacts is also indicated by the plots below which show the 6 hour DO concentration thresholds in the Sheaf and Porter Brook caused by a standard rainfall event falling on the sewer system. The two key impacts are caused by the Millhouses CSOs at the top of the Sheaf and Sylvester Gardens CSO at the bottom of the Porter Brook.





The top ranking in terms of impact of the overflows at Millhouses Park and Sylvester Gardens was confirmed by the continuous Sonde data collected during the river survey, and also by the interim mass balance calculations that had been carried out during the survey.

The river model calibration exercise indicated clearly that the dominant processes governing water quality processes in the Sheaf and Porter Brook are advection and dispersion, and that phase changes of pollutants are relatively insignificant by comparison. This is a product of the geometry and gradients of the rivers, which result in relatively short residence times of pollutants in the river system within which biochemical processes can occur.

The most important contributions therefore to dissolved oxygen levels in the river during storms are the upstream boundary DO levels and the DO levels in the CSO spills. The latter tend to dominate because CSO hydraulic spill rates are very significant in comparison with the relatively low base river flows.

A final key finding from the study was that water quality in the Porter Brook and Sheaf has relatively little impact on the Don because flow rates in the Don are much higher.

Conclusions

The programme was successful in that the original objective was achieved of ranking the CSO's in terms of the impact on the river. A full analysis of the impacts has been carried out and it should be noted that the CSO's were not ranked in the same order as would have been achieved if only volumetric or even total BOD loads were considered.

During the study a number of risks which were anticipated occurred. Problems with climate and river modelling software were resolved and did not affect the outcome of the study.