“TVP” - “ICS” and “RTC” in Oldham

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Introduction

This paper presents the background to the European Union (EU) funded Technology Validation Project (TVP), introduces the Integrated Catchment Simulator (ICS) software, developed as part of the project and discusses the initial results of its use in developing a Real Time Control (RTC) strategy for the Oldham pilot project.

The TVP Project

The TVP project is concerned with improving the traditional planning and management technology and procedures for the urban wastewater sector.

Traditionally, the main elements of the urban wastewater system; the sewered catchment, the treatment works and the receiving waters, have been managed separately, although, in reality, they are closely interrelated. This traditional approach was governed by a number of issues, not least, the lack of appropriate tools and procedures for integrated planning. Consequently, planning solutions could not be optimised in terms of environmental benefit and the balance between operational and capital expenditure.

Aims of the Project

The project objective was to demonstrate that an integrated approach to wastewater catchment wide planning can now be practical and cost effective. This new integrated approach is based on the use of improved planning and management procedures combined with integrated software tools.

Partners

The project team is made up of a group of R&D and consulting organisations in the wastewater sector, national associations and environmental agencies, as well as a number of end users, from six European member states. For the Oldham Study the partners were; DHI, who were also lead partner, co-ordinator and contractor of the project, and technology provider; WRc, who were core partners with DHI and were technology providers to end users in the pilot studies; and North West Water, as end users of integrated planning and management technologies for wastewater systems.

Pilot sites

Six pilot sites were chosen to demonstrate and validate the integrated approach and the corresponding technology. These were located in Barcelona, Bordeaux, Genoa, Helsingborg, Oldham and Venice. The pilot studies cover the full range of the technological and procedural challenges facing planners and operators. The pilot study areas cover 5 EU member states with approximately 200 million inhabitants, ensuring that dissemination of the projects achievements is successful.

Selection of Oldham

The specification for the pilot study areas was that they should comprise a discrete, self contained catchment with each of the three main components of an urban drainage system; a combined sewer system, a wastewater treatment works and a receiving water. Additionally, the area should currently suffer substantial and recognised environmental problems in the receiving water associated with performance of the urban drainage system.

The Oldham system was selected as an appropriate demonstration site for the TVP project as it fulfilled the above criteria and had recently been the subject of a UPM study. The development of the technology to link integrated modelling to RTC solutions, as proposed in the TVP project, is seen by North West Water to be important in the development of cost effective solutions in the future.

The Oldham Study Area

The town of Oldham lies in the Pennine hills to the north-east of Greater Manchester and has a population of approximately 180,000. The study area is served by the Oldham WwTW. The present works comprises two separate treatment streams, with some integration between the plants after primary treatment. The final effluent from the works discharges to the Wince Brook, a small watercourse carrying approximately 2 m3/s of flow. This joins with the River Irk three kilometres downstream of the works, which then flows south towards the centre of Manchester.

Wince Brook also receives spills from the Oldham WwTW storm tanks, the “Formula A” overflow at the inlet to the works and the numerous CSOs within the Oldham wastewater network. The Oldham WwTW has a current final effluent consent of 30 mg/l BOD and 45 mg/l suspended solids. Improvements to the works, targeted over the next five years, aim to bring final effluent quality up to 10 mg/l BOD and 3 mg/l ammonia.

The upgrading recommended by the Oldham UPM study required significant investment. The aim of the TVP project, therefore, was to carry out a desk study to demonstrate whether the adoption of a fully integrated, RTC based solution could significantly reduce the required expenditure.

Project Scope

The demonstration project focuses on the Oldham sewer system and WwTW and their effect on the Wince Brook. The UPM solution developed for this part of the system focused on reducing spills from the WwTW inlet overflow by enlarging the available storage tank capacity. Models of the sewer and WwTW were developed and run independently with their results being processed and fed into the river model.

The TVP project aimed to demonstrate by comparison with the UPM results the benefits of adopting an integrated approach to solution development through the use of the ICS software. In addition, the opportunities of considering the river and WwTW together with the network as part of an integrated RTC solution enabled a wider scope of solution to be considered.

Concepts behind the ICS

Experience of applying the Urban Pollution Management planning procedure has identified areas for refinement and improvement. One key area that has advanced rapidly is the degree of computational power now available to drive the data hungry mathematical models. The limitations posed by the current models necessitate restricting their use to only the most complex of problems.

Data manipulation between the models is laborious and does not facilitate assessment of the interactions between the various sewer, treatment works and river components of a catchment wide study. Development of an integrated tool which comprises all these elements opens up the scope for greater understanding of catchment behaviour and, in particular, to investigate amelioration schemes utilising RTC principles

The requirements of the Integrated Catchment Simulator would clearly have to incorporate the need for speed to allow for comprehensive assessment under a variety of conditions as well as providing accurate and reliable results. All this presented in a form that is easily understood by all.

The ICS development Process

The ICS has been developed jointly between DHI and WRc. The development process has progressed in a number of stages;

- Level 1 required rationalisation of the file format and determinands for the component models. The models would then run sequentially although manually.

- Level 2 saw the development of the global simulation control centre, which facilitates internal file transfer allowing catchment wide simulations.
- Level 3 enabled longer term continuous simulations to be carried out with feedback from downstream to incorporate RTC. The models run in parallel with the simulation automated. This is the extent of current ICS development.
- Level 4 looks to the future with potential to develop links to SCADA to use the ICS as a control tool with a predictive capacity to assess likely short term future impacts.

Setting up the ICS at Oldham

The existing HydroWorks models of the sewered catchment were simplified and converted to MOUSE and the STOAT model of the existing works was enhanced to include the upgrading identified in the UPM study. Slight modifications were also made to the existing MIKE11 model of the River Irk and Wince Brook catchment.

A data collection survey was carried out to establish a set of validation data for a number days including both dry and wet conditions. These data were used to confirm that the calibration of the models was still appropriate.

The three models were then included in the ICS and integrated at the works inlet and at the points where CSO and storm tank spills and the WwTW final effluent enter the river.

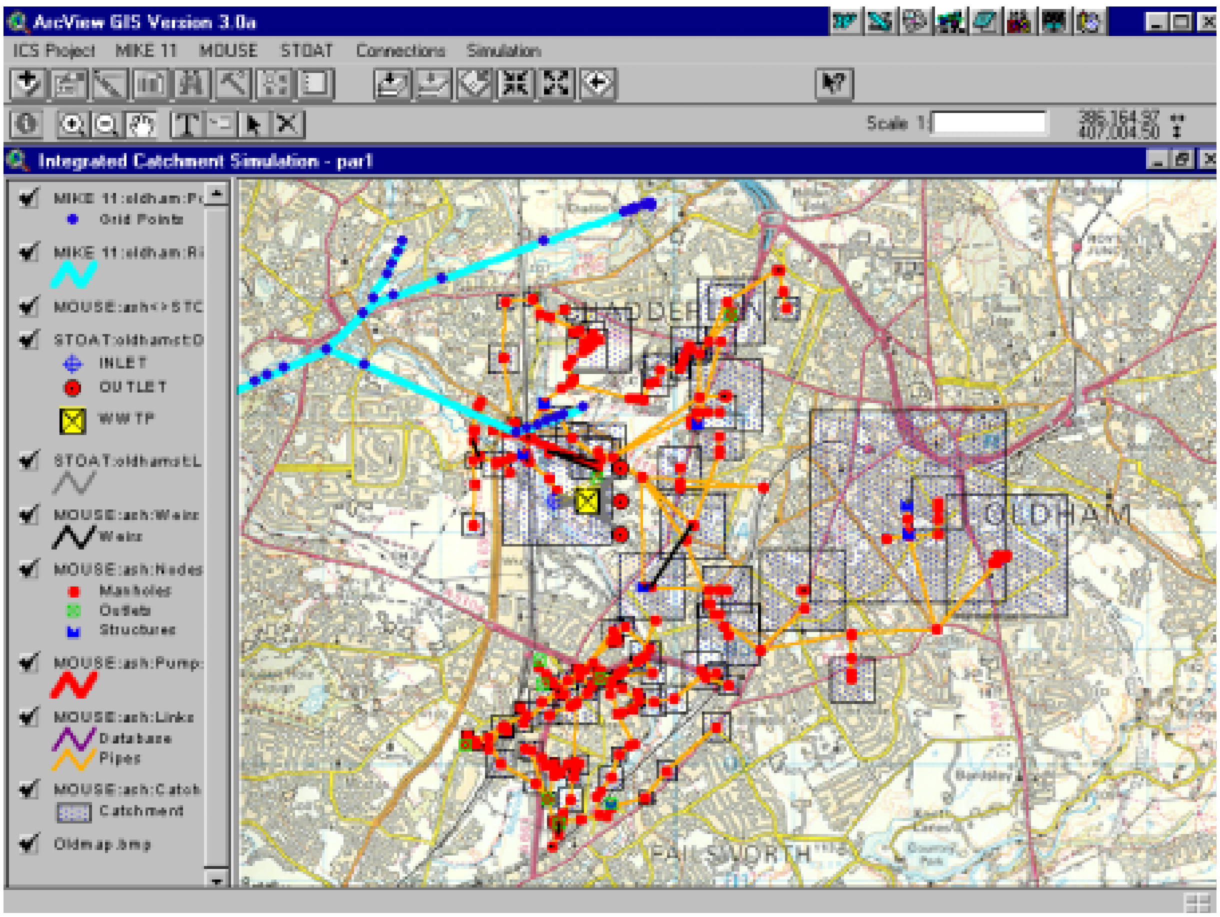

Figure 1: Plan view of Oldham catchment in the ICS

The performance of the integrated ICS model was tested by running a single event from the Oldham STORMPAC rainfall series and the runoff, spill volumes and resultant Dissolved Oxygen (DO) levels in the watercourse were compared with results from the individual models. This comparison proved the validity of the integrated model and, therefore, that it could be used for solution development.

Baseline Solution

The UPM study developed an upgrading solution by building and verifying models of the sewer, WwTW and river system and using these models to define the performance and critical conditions in the river. From this, simplified mass balance tools were developed and iterations were made with these tools to identify the size of storage required to ensure compliance in the river.

However, a baseline run needed to be carried out using the detailed models to represent the upgraded solution. This produced results against which all other results could be compared to allow a meaningful quantification of the benefits of the ICS and RTC.

Analysis of the UPM study results identified several combinations of storm event, sewer and river flow and quality which were critical for DO and ammonia in the river. One of these rainfall events was selected and run with the ICS model of the UPM solution to establish the UPM baseline performance.

The performance of all upgrading solutions developed as part of the study was compared against the baseline solution.

RTC Strategy Development

Results of running the converted MOUSE model with a 1 in 1 year return period storm showed considerable potential for storage mobilisation in the Oldham Deep Interceptor Sewer (ODIS). Examination of the interceptor long section identified three sections laid at a similar gradient which are hydraulically independent, each being separated by a steeper section. It was decided that the modelling of in-line gates upstream of these steeper sections would allow the mobilisation of storage in each of the three uniform sections. The idea would be to increase utilisation of the in-line storage and in doing so, reduce the need for extra storm tank storage at the works.

Accordingly, three in-line gates - GATE1, GATE2 and GATE3, arranged in series, were added to the ICS model. The first stage of using the ICS was to base the control of GATE 3 around the level entering the WwTW. GATES 1 and 2 then act in series with GATE 3 based on PID controllers. Following on from this an integrated control strategy is now being developed which would activate the in-line storage in the sewer, with control based on water quality in Wince Brook. The reason for controlling storage mobilisation based on quality rather than a hydraulic determinand is the need to optimise the use of the assimilative capacity of the river thereby reducing operational (pumping and treatment) costs. If water quality in the river, and thus the available assimilative capacity is known then, within reason, spills can be controlled to balance environmental and operational needs.

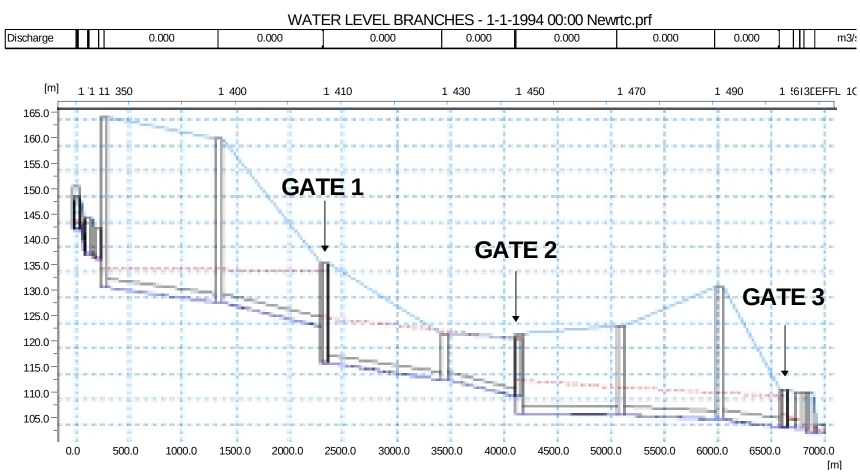

Figure 2: Long section of ODIS showing Gates 1, 2 and 3

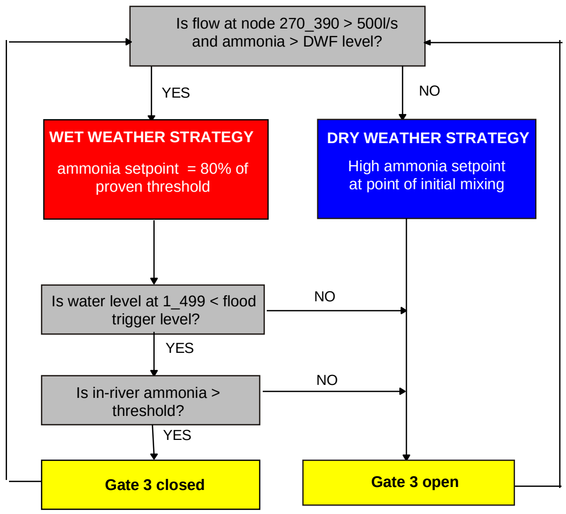

Figure 3 Flow chart showing RTC strategy

For the control strategy, GATE3 operates as a primary-regulator, controlled by runoff rates in the catchment and by the pollution levels in the river. The other two upstream gates (GATE2 and GATE1) act in series with GATE3, in order to achieve synchronised filling and emptying of the in-line storage. A flow chart of the control strategy is presented as Figure 3, which is discussed in the following section.

Dry Weather Default Scenario

GATE3 is modelled as a PID-controlled device. The set-point for this regulator is the ammonia concentration in Wince Brook at the point of initial mixing of the WwTW outflow and the CSO spills as they enter the river.

In dry weather the default position of Gate 3 is open. The simulation starts with a default set-point value for ammonia which represents the dry weather conditions. This set-point is set significantly higher than dry weather in-river ammonia values to ensure that in dry weather the gate remains fully open.

The control strategy switches from the dry weather to the wet weather scenario when discharge from the largest of the Oldham subcatchments exceeds a threshold of 500l/s at node 270_390. This threshold was selected to avoid the active mobilisation of storage for very small runoff volumes, not likely to cause overflow from the system. In reality the switch between dry and wet conditions could be triggered by a threshold rain intensity value monitored by a network of raingauges.

Wet Weather Scenario

When the wet weather scenario is triggered, the set-point for ammonia is adjusted in relation to the water level immediately behind GATE3. For the baseline assessment runs the ammonia levels at the point of mixing were examined to determine a limiting ammonia threshold. Ideally, a critical BOD threshold, would be determined based on downstream DO at the point of worst impact, to protect water quality but, whilst on-line ammonia monitoring is established technology, at present on-line BOD monitoring has not been developed to be sufficiently fast and accurate for use in active control.

When the stored volume in ODIS is lower then approx. 80% of the total available storage, the ammonia set-point in the river is set to a level which equates to 75% of the limiting threshold. When the in-river ammonia concentration begins to increase (as a consequence of increased emissions from the system), the gate will be closed gradually and its position modulated to attempt to maintain the desired set-point.

Flooding/Surcharge Protection

Correspondingly, this will cause the level behind the gate to increase as storage is mobilised. When the level approaches a freeboard for surcharge and flooding of 2m, an override control rule is activated which causes GATE3 to be raised. In doing so, the water level is reduced. This set-point equates to a level of 108m above Ordnance Datum (AOD),

This is achieved by gradually increasing the ammonia set-point, as a linear function of the water level in the sewer. The function is defined so that when the storage is full the set point value is very high, thereby causing the gate to open. If the level continues to grow further, the high set-point would keep the gate open, maintaining peak pass forward flow.

Storage Emptying

After a rain event and when the WwTW storages and all the CSOs have stopped spilling, storage emptying can begin. The "post-rain" situation is recognised by the following variables:

- Runoff (or rain intensity) has fallen to (or almost to) zero.
- DO at the "point of critical impact", i.e. further downstream in Wince Brook has returned to the dry weather value

When the "post rain" situation has been recognised, the ammonia set-point is set to a value equal to the upper limit of ammonia in DWF, i.e. slightly above normal. This will cause the GATE3 to release as much water as it can pass through the WwTW to full treatment, i.e. not causing an increase of ammonia. If more water is released, the WwTW would be bypassed and the in-river ammonia would increase, causing the gate to close and thereby reduce the pass forward flow.

Emptying is continued as long as the water level in the pipe behind the gate is raised above the dry weather level. When the level falls below this threshold, the system returns to the dry weather strategy, i.e. the gate is fully opened again. If a rainfall event is detected again during the emptying process, the system returns back to the "rain strategy" and the gate is closed.

Control of GATE2

GATE2 and GATE1 are controlled in relation to the water level in the next downstream segment of ODIS, i.e. by level behind the next downstream gate. The gates are controlled by a PID device, with a water level set-point immediately behind the next gate downstream, as follows:

For example, if the level behind GATE3 is at the DWF level (105m AOD), the set-point for GATE2 is kept low (110m AOD), so that the gate remains open. When the level at GATE3 falls in the range 105.00m to 108.50m (AOD), the set-point will change linearly between 111.00m and 117.50m (AOD).

If the level behind the GATE3 raises above 108.50m (AOD), the set-point is set to a constant 117.50m, i.e. no higher level then 117.50m (AOD) is allowed in the ODIS behind GATE2.

GATE1 and GATE2 therefore close in unison, ensuring uniform storage utilisation.

WwTW Storm Tank Utilisation

As shown in Figure 4, storage at the upgraded works will be provided in three locations, a new blind storage tank (2000m^3), a new storage tank (7000m^3) and the refurbished, existing storm tanks (6000m^3). The filling of these storage tanks is controlled by a set of process logic controllers, (PLCs). The aim of this is to balance the utilisation of the available storage to ensure that no spill occurs when there is spare capacity in any one of the tanks.

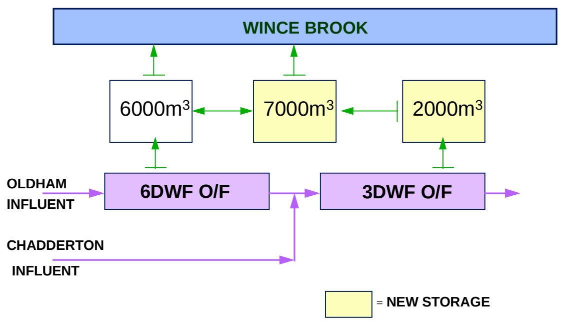

Figure 4 Schematic of the planned storage at Oldham WwTW

In storm conditions, filling of the storm tanks begins when inflows exceed 3DWF and overflow into the 2000m^3 new storage tank. This tank is blind and retains the first flush effects. When this blind tank is full, flows are routed into the new 7000m^3 storage tank which comprises a number of compartments which fill sequentially.

If the level in the 7000m^3 storage tanks is higher than that in the refurbished 6000m^3 storage tanks than a high level overflow is activated which uses a PLC to balance the flows between the two storage tanks. The 6000m^3 storage tanks are also filled by spills directly from the 6DWF overflow and the PLC balances the storage utilisation to ensure that flows are passed to the new storage tanks before a spill occurs from the 6DWF outfall. Spills from the storage tanks only occur when they are all completely filled.

WwTW Storm Tank Emptying

After the cessation of a rainfall event, the trigger for the emptying of the storm tanks back into the treatment stream occurs when inflows have reduced below 2500m^3/hour. The order in which the storm tanks are emptied is also controlled by a PLC controller, which ensures that the 2000m^3 tank is returned to the treatment stream first, followed by the new 7000m^3 tank and finally the 6000m^3 tank. Each of the tanks are emptied at a rate of 1500m^3/hour.

The PLC control of the works storage utilisation and emptying is represented within the ICS and is integrated with the RTC control of the on-line storage by the effects, which the returns have in the river at the point of initial mixing.

Results Comparison

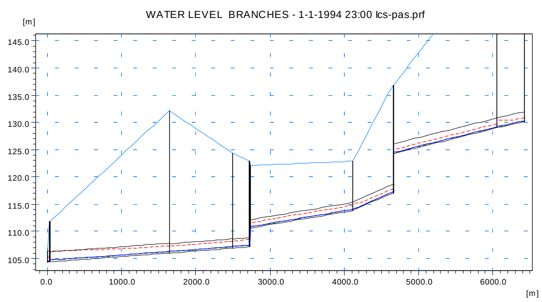

Figure 5 Longitudinal profile through ODIS (uncontrolled flow)

The initial results of the project with the first stage of the control based solely on the hydraulic level entering the WwTW have shown a significant mobilisation of storage within ODIS. Figures 5 and 6 show the resulting water level in ODIS with and without control.

Approximately, 10,000m^3 of storage was utilised in ODIS, which offers the potential for significant cost savings over the original UPM and NEP solutions. The next set of results will show how the storage within the ODIS is further mobilised when the RTC strategy is also based on in-river quality.

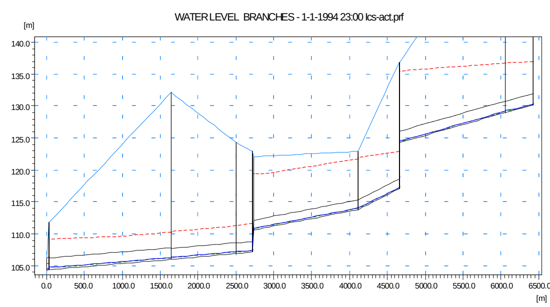

Figure 6 Longitudinal profile through ODIS (controlled flow)

Conclusions

ICS has demonstrated that through the development of integrated control strategies suitable CAPEX/OPEX balances can be developed which ensure savings in excess of those achieved by the UPM study.

Discussion

Question Adrian Saul Sheffield University

What consideration was given to sediments in the RTC strategies?

Answer

The main effect would be on the blind tank. We want to look at effectively controlling the 7,000 m^3 tank?

Question Gerard Morris Environment Agency

In the future as we move to risk based permitting have you done risk assessments on the control and consenting system, model wrong, control system down, gate or pump failure?

Answer

We are addressing this, the Bolton pilot study is looking at these issues in some detail.

Question John Blanksby Sheffield Hallam University

I believe there will be problems with sediment deposition in the flat inlet sewer, have you looked at this?

Answer

We do not yet have a feel for the likely problem areas as we are only looking at a single event. The default is the gate open so in dry weather there is good sewer flushing. The long time series runs will address this issue as it is very important.