Southwell Urban Pollution Management Case Study

James Playfair –Atkins Water
Sella Ariyadasa – Severn Trent Water

Abstract

An Urban Pollution Management (UPM) study for Southwell, Nottinghamshire, was undertaken on three Unsatisfactory Intermittent Discharges (UID) to determine their impact on the receiving water courses. The InfoWorks UPM analysis tool was applied to a previously verified hydraulic model using simplified assessment techniques and default water quality parameters combined with physical river survey data. Previously, a modelling study based on traditional hydraulics only approaches had suggested CSO improvement schemes with storage at each of the UID's. The results gained from the UPM water quality analysis indicated that the CSO's did not have a detrimental impact on the water quality and that the improvement schemes suggested in the previous study were not required for the CSOs to meet water quality objectives. The study therefore demonstrated significant cost savings to the client, Severn Trent Water, and the value and benefits to be derived from the UPM approach.

1. Introduction

1.1 The Southwell Study Area

The Southwell catchment lies approximately 11km to the west of Newark and covers a total area of 250ha. The catchment drains from the west towards the River Greet and finally to the River Trent. Sewage from Southwell drains to the STW by gravity. A number of small outlying village catchments pump directly to Southwell STW.

There are five CSOs in the catchment, all of which are situated in the main town of Southwell: Church Street CSO, Riverside CSO and Newark Road CSO were considered UIDs by the EA for both water quality and aesthetic reasons. Figure 1 shows the study area of Southwell town and the key CSOs.

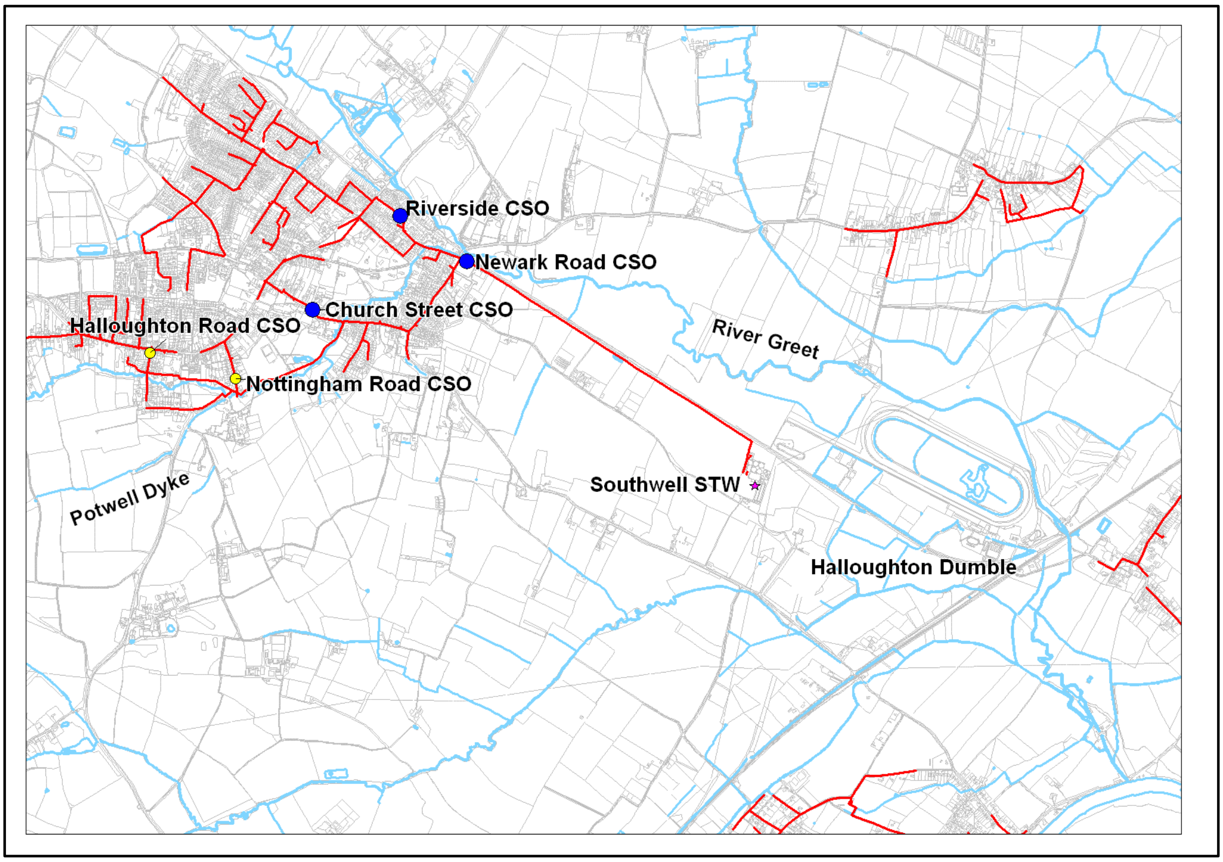

Figure 1 – Study Area

The principal watercourse is the River Greet, which enters the catchment in the north and flows southeast along the northern edge of Southwell town. The only other significant watercourse is the Potwell Dyke, which flows north east along the southern edge of Southwell before joining the River Greet. Southwell STW storm tanks discharge to Halloughton Dumble, which then joins the River Greet some 4km downstream of Southwell Town.

1.2 Previous Studies and Proposed System Improvements

A modelling study to investigate hydraulic improvement options for the town was completed in 1999. The drivers for this were the CSO's. The study confirmed that the hydraulic performance of the Riverside and Newark Road CSOs was unsatisfactory and that the CSOs did not have adequate screening. The Halloughton Road, Nottingham Road and Church Street CSO's all passed forward Formula A but were considered unsatisfactory with regard to aesthetic control.

As a result, a programme of CSO improvement schemes was considered for Nottingham Road, Riverside, Newark Road and Church Street. It was recommended that storage be provided at these CSOs to achieve satisfactory spill regimes by maintaining the current pass forward flows.

Following the completion of the modelling study, the Environment Agency deemed Riverside CSO, Newark Road CSO and Church Street CSO to be UIDs, in terms of aesthetics and water quality. As a result a simplified UPM study was commissioned by Severn Trent Water to investigate the performance of the CSOs and their impact on the water quality of the receiving water courses.

2. Objectives of the UPM study

The aim of the UPM study was to determine the water quality impact of the three UID discharges on Potwell Dyke and the River Greet, and then to develop improvement schemes where required. The impact of STW storm discharges on the water quality of the receiving watercourses of Halloughton Dumble and the River Greet was also considered.

3. Environmental Objectives and Issues

The environmental planning framework was based on water quality standards set by the Environment Agency. These are outlined in Table 1. No water quality target standards were supplied for Potwell Dyke, as it is unclassified by the EA. For the purposes of this study, a conservative approach was taken and it was assumed that the Potwell Dyke should meet the same performance criteria as the receiving water to which it ultimately discharges (the River Greet).

River	RE Classification	Fundamental Intermittent Standard
River Greet	RE2	Salmonid
Potwell Dyke	Not Classified (Assumed RE2)	Not Classified (Assumed Salmonid)
Halloughton Dumble	RE4	Sustainable Cyprinid

Table 1 - Performance Criteria for Watercourses in Southwell

<u>Fundamental Intermittent Standard</u>

This is expressed in terms of concentration and duration thresholds for a range of return periods for individual pollution events. In order for the quality of the watercourse to result in no long term detrimental effects on the designated ecosystem type the Dissolved Oxygen and Unionised Ammonia must not breach the thresholds more frequently than shown in Table 2.

Return Period (Sustainable Salmonid)	Dissolved Oxygen mg/l (6 hour standard)	Un-ionised Ammonia mg NH3 – N/l (6 hour standard)
1 Month	5.5	0.025
3 Months	5	0.035
1 Year	4.5	0.040
Return Period (Sustainable Cyprinid)	Dissolved Oxygen mg/l (6 hour standard)	Un-ionised Ammonia mg NH3 – N/l (6 hour standard)
1 Month	5	0.075
3 Months	4.5	0.125
1 Year	4	0.150

Table 2 - FIS Criteria

With regards to the FIS criteria 12 1-month exceedences, four 3-month exceedences or one 12-month exceedences are permitted over a year.

River Ecosystem (RE) Classes

This method of water quality classification is to define high percentile criteria. These values (DETR, 1997) have been established by extrapolation of the 90%ile values for BOD and Total Ammonia and are outlined in Table 3.

Class	BOD (ATU) mg/l 99 percentile	Total Ammonia mg N/l 99 percentile	Un-ionised Ammonia mg N/l 99 percentile
RE2	9	1.5	0.04
RE4	19	6	n/a

Table 3 - RE Standards

In all river reaches, 14.6 exceedences of the 6-hour event are permitted per annum with regards to relevant RE threshold values. The actual concentration threshold varies depending on the RE Class, for example, for RE2 class the BOD threshold is 9mg/l, whereas for RE4 the BOD threshold is 19mg/l.

4. Assessment Approach

At the start of the study, the available tools and requirements were considered for completion of the UPM analysis. A hydraulic model of the sewerage system for Southwell was already available but rainfall data and water quality data were required.

A previously verified hydraulic model was already available for Southwell town itself. A second, smaller model was required for a number of outlying villages which also discharge to Southwell STW and subsequently combined with the main model. Surface water sewers and land drains were also added to the existing model as they discharge to the study water courses.

Using a detailed InfoWorks model meant that a more realistic assessment of the performance of the system could be simulated in terms of spill frequencies and volumes at the CSOs. This negated the need to build a second, more basic sewer model for the water quality analysis.

The UPM tool within InfoWorks was used, as opposed to more simplified approaches (such as SIMPOL), for three reasons:

1. InfoWorks allows the use of a baseline detailed hydraulic model during the analysis and is therefore more realistic than the SIMPOL spreadsheet approach which uses simple tank representations to simulate the CSOs and watercourses.
2. The use of InfoWorks allows the utilisation of RTC files. This was especially useful during this study as it allowed the simulation of the storm tank emptying sequence during dry conditions, and thus how spills may occur during conditions where the tanks are partly full.
3. Longer duration rainfall events can be simulated with an InfoWorks model to determine the effects of successive storms and drain down times.

5. Rainfall Time Series

A 20 year stochastic rainfall series was generated for the Southwell catchment using StormPAC. Calibration data was available in the form of 15 years of hourly rainfall data as supplied by Severn Trent from the EA raingauge at Sutton in Ashfield. SMD data was also obtained from Severn Trent Water that was based on EA measured monthly averages since 1996.

An inter-event dry period of ten hours was used, as this is the approximate time required to empty the storm tanks at the STW. This is an important consideration when investigating UID or storm tank performance, and the effect of storage on this performance, as it allows the interactions between successive rainfall events to be assessed. For example, two small events in succession may cause a spill at the STW storm tanks as the first event part fills the tank and the second causes a spill. In contrast, if occurring individually, these events may be too small to cause a spill at the STW storm tanks.

In total 118 rainfall events were imported into InfoWorks for use in the water quality analysis, representing a typical year.

6. UPM River Impact Assessment

6.1 Sewer Water Quality

In order to calculate the pollutant loads from the CSOs and storm sewer discharges in the InfoWorks sewer model, water quality parameters were required. It was agreed with Severn Trent Water to use the default pollutant loadings and wash-off parameters, and QSIM simulations were carried out for each event so that the time varying pollutant loads within the spills at the CSOs were predicted.

6.2 River Data

A significant amount of data is required to set the boundary conditions for the river sections. Some of this data was obtained by way of survey, some from contour maps and some through engineering judgement.

Cross sectional data for 20 river sections were gathered from survey. This included bed level, river width and side slope. The data gathered from the surveys was entered as a UPM river data group in InfoWorks. A UPM analysis requires that the watercourses be split into distinct reaches, each of which can contain a maximum of six sub-reaches.

For this study, Potwell Dyke was split into two reaches, Halloughton Dumble one reach and the River Greet five reaches. Each reach contained six sub-reaches (based on the survey data or interpolated points). Figure 2 shows the extent of each of the river reaches. Storm water and CSO discharges were defined for each reach and were added in a cumulative manner. Such simplistic water quality assessments are conservative in that the lowest reach contains all the Southwell CSO and storm discharges, and no account is made of re-oxygenation or breakdown of pollutants within the river. River cross-sections for reaches Greet 4 and Greet 5 were based on the last cross-section in Greet 3, due to problems gaining access and carrying out surveys for this part of the Greet. Due to a lack of survey data, as a result of difficult access, the physical data for Halloughton Dumble was assumed to be similar to Potwell Dyke.

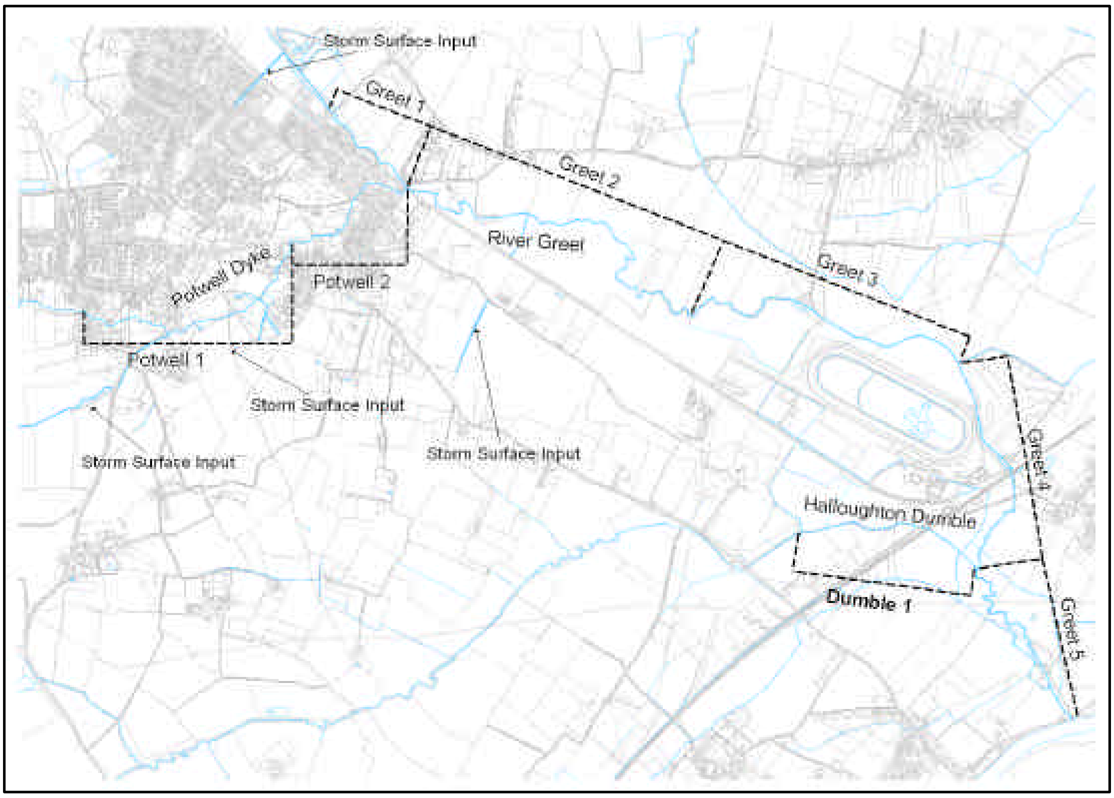

Figure 2 – River Reaches

6.3 Flow Data

Flow data was obtained from the EA. For the analysis, two distinct sets of flow data were created for each river input. The first contained 'river dry weather flow' and this was used to approximate the summer flows, and to subsequently allow the effect of CSO discharges to be assessed against worst case, low river flows. This was an important consideration, as it may be in the summer when river flows and dilution are lowest that the greatest deterioration in water quality is observed or predicted due to CSO spills. This is especially significant due to the flashy response of the sewer system, yet slower flow response of the River Greet.

The second set of flow data was an average of measurements taken over a year. This data was used for 'normal' flow conditions to be used for a typical annual assessment of water quality parameters on higher river flows.

Where two rivers converge, the flows (e.g. Potwell Dyke and River Greet) were added together to account for the increase in flow.

6.4 River Water Quality Data

Water quality parameters were also supplied by the EA, based on measured data. A mean and standard deviation was determined for each water quality data set for each river input. These were used as the upstream boundary conditions.

Where two rivers converge, e.g. Potwell Dyke and the River Greet, a mass balance calculation was carried out to produce the increased flow input and the respective pollutant concentrations.

The default parameters in the UPM analysis tool were utilised to represent the mixing of pollutants in the CSO spills and river flows. The use of the default parameters was necessary due to the lack of any measured data. The values used are considered to be conservative.

7. Baseline Results

Two sets of simulations were carried out. One contained all rainfall events for the whole typical year which was analysed with mean river flows, and the second contained the events that occur from May to September within this typical year rainfall pattern. These were analysed with the low summer flows. This was to investigate if there was a rise in the concentration levels during the low river flows of the summer months or whether winter storms had more of an impact in increasing concentration levels.

A summary of the results from the UPM study is outlined in Table 4.

	RE Standards (Exceedences per year)			FIS Standards (Exceedences per year)								
River Reach	BOD	NH3	unNH3	Initial un NH3			D/S DO			D/S unNH3		
				1 month	*3 months*	*1 Year*	*1 month*	*3 months*	*1 Year*	*1 month*	*3 months*	*1 Year*
Potwell Dyke 1(Summer)	1.5	0.3	0.1	0.2	0.1	0.1	0	0	0	0.2	0.1	0.1
Potwell Dyke 1(Whole Year)	3	2.7	0.9	2.3	1.3	0.9	0	0	0	2.3	1.3	0.9
Potwell Dyke 2 (Summer)	3.3	1.7	0.6	1.5	0.6	0.6	0	0	0	1.5	0.6	0.6
Potwell Dyke 2 (Whole Year)	4.1	3.2	0.9	0.8	1.1	0.9	0.1	0	0	1.8	1.1	0.8
Greet 1(Summer)	2.6	0	0	0.1	0	0	0	0	0	0.1	0	0
Greet 1(Whole Year)	0.9	0	0	0	0	0	0	0	0	0	0	0
Greet 2 (Summer)	4.4	1	0.3	0.9	0.3	0.3	0	0	0	0.9	0.3	0.3
Greet 2 (Whole Year)	7.1	0.8	0.1	0.7	0.1	0.1	0	0	0	0.7	0.1	0.1
Greet 3 (Summer)	4.7	1.1	0.6	1.3	0.8	0.6	0	0	0	1.2	0.8	0.6
Greet 3 (Whole Year)	7	1.1	0	1.3	0.1	0	0	0	0	1.2	0.1	0
Greet 4 (Summer)	4.9	1.1	0.4	1	0.6	0.4	0	0	0	1	0.6	0.4
Greet 4 (Whole Year)	7.8	1	0	1.2	0.1	0	0	0	0	1.2	0.1	0
Greet 5 (Summer)	9.1	7.9	3.8	6.7	4.7	3.8	0	0	0	6.7	4.7	3.8
Greet 5 (Whole Year)	25.2	15	2.7	10.2	5	2.8	0	0	0	10.2	5	2.8
Halloughton Dumble (Summer)	8.7	4		2.9	1.7	1.1	0.5	0.3	0.1	2.8	1.6	0.9
Halloughton Dumble (Whole Year)	28.9	4.9		6.1	1.6	1.1	1.3	0.7	0.5	5.5	1.3	0.8

Passes standard
Standard breached

RE threshold values

Threshold (mg/l)	**RE 2**	**RE 4**
BOD	9	19
NH3	1.5	6
unNH3	0.04	n/a

Pollutant level must not exceed thresholds 14.6 times per year

FIS threshold values

	Sustainable Salmonid Return Period			**Sustainable Cyprinid Return Period**		
Threshold (mg/l)	1 month	3 months	1 Year	1 month	3 months	1 Year
Initial unNH3	0.025	0.035	0.04	0.075	0.125	0.15
DO	5.5	5	4.5	5	4.5	4

Values based on a 6 hour duration event

Table 4 – UPM Results

As can be seen in Table 4, the entire length of Potwell Dyke and four sections of the River Greet pass all water quality standards. However, the last section of the River Greet and Halloughton Dumble exhibit exceedences of the limits set. This indicates that the CSOs have no significant direct impact on the watercourses in Southwell.

In general the water quality impacts appear to be more pronounced during the summer months. This is due to the lower flows present in the rivers, as during higher flows a higher degree of pollutant dilution is experienced.

General Discussion

Low summer flows cause the proportion of exceedences to increase for the summer months when compared to the analysis over the full year. This is particularly the case for Potwell Dyke 1, Greet 1, Greet 2, Greet 3, and Greet 4, where over half the whole year BOD exceedences occur in the five summer months when the low river flows are used. Whilst this highlights the importance of considering the summer months and low flows, this analysis does not show that the low river flows in the summer is a direct cause of failure at any of the CSOs in Southwell Town, as initially suspected.

With regard to Greet 5 and Halloughton Dumble, which do not meet RE and FIS criteria as a result of the STW storm tank spills, the summer low river flow exceedences are a much lower proportion of the whole year results. This indicates that more water quality impact is associated with large, long duration winter spills from the storm tanks, rather than spills during the summer months when river flows are lower.

The results show that the UIDs in Southwell do not have a significant impact on the River Greet or Potwell Dyke. Therefore, no hydraulic improvement schemes were required to reduce the spill frequencies further at these CSOs. The only schemes required are screens to reduce the aesthetic impact. However, a scheme has been proposed to close Riverside CSO. This is due to poor access as it is located in the rear garden of a property. All flows are passed downstream to Newark Road. This scheme has been shown not to detrimentally affect the water quality.

8. Summary of the key modelling assumptions

Default sewer water quality parameters and river mixing parameters were used in the UPM study. No measured data or verification was undertaken regarding these parameters. The cumulative effect of the CSO discharges in the river acts to over predict the pollutant loads in the lower reaches of the water courses and when combined with the default parameters produces results that are more conservative than using measured data.

A non verified model was used for the outlying villages, based on conservative assumptions resulting in the spills at the STW being conservative. Furthermore, no account of the treatment /settlement in the storm tanks has been made. Again, this is likely to lead to conservative predictions of pollutant loads at the STW.

9. Conclusions

InfoWorks UPM tool is a suitable tool to investigate the water quality impact of CSO discharges on river reaches. Despite the default hydraulic parameters being used, a number of assumptions relating to the water quality and river modelling have been utilised. These assumptions are conservative and the study has demonstrated that there is no detrimental water quality impact from the CSOs.

This UPM study showed that river water quality in Southwell town is acceptable and within the required RE and FIS criteria with both summer and average river flows. However, the modelling results from the UPM study suggest that intermittent water quality parameters are breached downstream of the STW.

Although previous studies showed that the CSOs in Southwell had a poor hydraulic performance, the UPM study shows that no action is required to improve water quality in Southwell town. There may be a need to carry out further investigations downstream of the STW to confirm whether there is a water quality problem in reality. As with the output from all models, the results have to be viewed in the context for which they were developed.

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