Cookstown Urban Pollution Management Study

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Introduction

This paper describes a simplified Urban Pollution Management (UPM) study undertaken by Binnie Black & Veatch in association with Ferguson & McIlveen on behalf of the Water Service of Northern Ireland. The specification for the study was determined by the environmental regulator for Northern Ireland, the Environment & Heritage Service, advised by WRc.

The location of the study was Cookstown in Northern Ireland and the aim of the study was to ensure that proposed upgrading works to both the sewer system and the treatment works would support achievement of an high quality sustainable salmonid fishery in the Ballinderry River which receives flows from Cookstown catchment. The study was undertaken using data that was, for the most part, already available at the start of the study and involved the construction of one new, simplified (SIMPOLv2) model. As such, the resource requirements for the study were relatively modest. However, the conclusions of the study are considered to be reliable and robust and fully meet the aims of the project.

The Cookstown Study Area

The study area is shown in Figure 1.

Figure 1 : Map of Cookstown area

Cookstown is a market town of approximately 15,000 population located on the north bank of the Ballinderry River some 10 km. due west of Lough Neagh. The area is subject to

substantial increase in the resident population, which is anticipated to grow to approximately 17,000 during the planning horizon up to 2030. The town is currently served by a combined sewer system, which incorporates 15 combined sewer overflows (CSOs). Sewage flows drain to the Killymoon Sewage Treatment Works (STW) sited on the north bank of the river. A major meat processing plant which is located to the east of the town, discharges its effluent, following pre-treatment, to the sewer system. The majority of the CSOs discharge storm flows into minor watercourses situated to the west or east of the town. Both of these minor watercourses, known as the Eastern and Western Ditches, flow into the Ballinderry River. Only the STW treated effluent, the storm tanks overflow and one CSO immediately upstream of the STW discharge directly to the Ballinderry River.

The Ballinderry River runs just to the south of the Cookstown urban area and, following its confluence with several significant tributaries, eventually flows into Lough Neagh. The river is an important habitat for indigenous salmonid species. A major tributary, called the Killymoon River, joins the Ballinderry immediately downstream of the STW effluent discharge point.

Environmental Objectives and Issues

The Ballinderry River has a river quality objective of Chemical General Quality Assessment (GQA) Class B "Good Quality" throughout the study area. This standard is currently achieved upstream of Cookstown, but downstream of Cookstown, the river quality falls to GQA Class D "Fair Quality". The minor water courses (Eastern and Western Ditches) have extremely low summer base flows and do not have specific river quality objectives.

It is considered that, in the future, in addition to meeting the GQA targets, the Ballinderry should be capable of meeting the UPM Fundamental Intermittent Standards (FIS) for dissolved oxygen and unionised ammonia for a Sustainable Salmonid Fishery.

All of the watercourses in the area are considered to be of moderate amenity value.

Proposed Urban Wastewater System Improvements

Prior to commencement of the UPM study, the Water Service had identified a scheme of proposed improvements to both the sewer system and the sewage treatment works.

The proposed sewerage improvements were identified as the result of a Drainage Area Planning study carried out in 1994. In summary, the proposals comprise:

- construction of several in-line storm sewage detention tanks within the sewer system;
- separation of substantial areas of combined sewerage and the construction of new storm sewers to convey the separated storm water runoff to the Eastern and Western Ditches;
- closure of twelve out of fifteen existing CSOs and refurbishment of the remaining three CSOs; and
- renovation of substantial lengths of existing sewer to overcome identified structural deficiencies.

The proposed CSO closures eliminate all CSO discharges to the Western Ditch, but leave the three CSOs discharging to the Eastern Ditch and directly to the Ballinderry River. Screening appropriate to the designated Moderate Amenity Use classification is proposed at all of the retained CSOs.

In addition, the EHS had specified that any CSOs discharging to the Eastern Ditch which were to be retained should incorporate storage sized in accordance with the recommendations of the Scottish Development Department (SDD) Guidelines. Due to the low base flow in the ditch, this requirement led to the provision of a total of approximately 1200 m^3 of storage at two of the three remaining CSOs.

The existing sewage treatment works was constructed in 1965 and is now both hydraulically and biologically overloaded. The effluent is consistently of poor quality and fails to meet its registered consent conditions. The STW is considered to be a major cause of the deterioration in river water quality from upstream to downstream of the Cookstown urban area. As a consequence of these considerations, the STW is regarded as totally unsatisfactory and a new works is to be built on the site of the existing works. The registered consent for the new works was agreed between Water Service and EHS prior to the commencement of the UPM study.

Objectives of the Cookstown UPM Study

The aim of this study was to evaluate the performance of the Cookstown wastewater system, incorporating the proposed improvements to both the sewer system and the new sewage treatment plant against the environmental criteria specified by the EHS, i.e.

- Fundamental Intermittent Standards for a Sustainable Salmonid Fishery;
- Chemical Quality Assessment River Quality Standards for Class B Good Quality.

These standards are set out in Tables 1 and 2 respectively.

Return Period	Dissolved Oxygen mg/l (6 hour standard)	Un-ionised Ammonia mgNH_3-N/l (6 hour standard)
1 month	5.5	0.025
3 month	5.0	0.035
1 year	4.5	0.040
Return Period	Dissolved Oxygen mg/l (1 hour standard)	Un-ionised Ammonia mgNH_3-N/l (1 hour standard)
1 month	5.0	0.065
3 month	4.5	0.095
1 year	4.0	0.105

Table 1 : UPM Fundamental Intermittent Standards for a Sustainable Salmonid Fishery

GQA Class	Dissolved Oxygen (% Saturation)	BOD Mg/l	Total Ammonia (mg N/l)
	10 percentile	90 percentile	90 percentile
A (Very Good)	80	2.5	0.25
B (Good)	**70**	**4.0**	**0.6**
C (Fairly Good)	60	6.0	1.3
D (Fair)	50	8.0	2.5
E (Poor)	20	15.0	9.0
F (Bad)	Less than 20	-	-

Table 2 : Chemical General Quality Assessment Standards

UPM Study Methodology

The methodology adopted for the study was specified by the EHS and was taken directly from the Urban Pollution Management Manual, Edition 2[(1)]. The key activities were:

Task 1 : Construction of a simplified integrated model of the sewer system, sewage treatment works and receiving river incorporating the proposed improvements.

This was achieved using SIMPOLv2 software. The closure of the majority of the existing CSOs allowed a simple model layout to be conceptualised, as shown in Figure 2. The bulk of the combined sewer system was represented in only two sub-catchments (S1 and S2). The areas where storm flows are planned to be separated from the combined system were included as two additional sub-catchments (S3 and S4) with zero continuation flow and all storm flows discharged to the watercourses. The continuation flows from S1 and S2 come together at the CSO controlling inflow to the STW which is represented by a further sub-catchment (S5) and a STW storm tanks module is included (S31). The river system is represented in three reaches commencing at the point of input of the STW effluent with reach divisions at the inflow of the Killymoon River and the Eastern Ditch. The downstream boundary of the study area was located at Ardtrea Bridge, some 10 km below the treatment works input.

Information for construction of the sewer module of the SIMPOL model was extracted from the HydroWorks model developed during the previous Drainage Area Planning exercise. However, much of the data relating to the physical configuration of the Ballinderry River had to be specially collected in the field.

Task 2 : Calibration of the SIMPOLv2 model.

Hydraulic calibration of the sewer module was achieved in the conventional manner using the results for a suite of 10 storm events from the HydroWorks model. Quality calibration was achieved using default values derived from reports produced by WRc for the Environment Agency[(2,3)] with allowance being made for the additional inputs from the meat processing plant. Variation in the quantity and quality of base flows was included in the model following conventional diurnal patterns in 6-hour time intervals. Simulated concentrations at the bottom end of the sewer system were compared with the limited historical quality data available at the STW inlet and found to be a slight to moderate overestimate. This was deemed to be acceptable as it would result in a conservative assessment of .impact on the receiving water.

The EHS provided estimates of whole year and summer flow distributions for the Ballinderry and Killymoon Rivers. Historical river quality data were available for the upstream reaches of both rivers. Default values were used for parameters such as BOD decay rates, etc.

Task 3 : Rainfall Time Series

A 10 year synthetic time series was generated using the STORMPACv3 software package. Calibration data were available in the form of a 15 year historical daily record from the Cookstown weather station. In addition, a set of 827 summer storms were extracted from the complete dataset to allow investigation of the critical conditions during the summer periods.

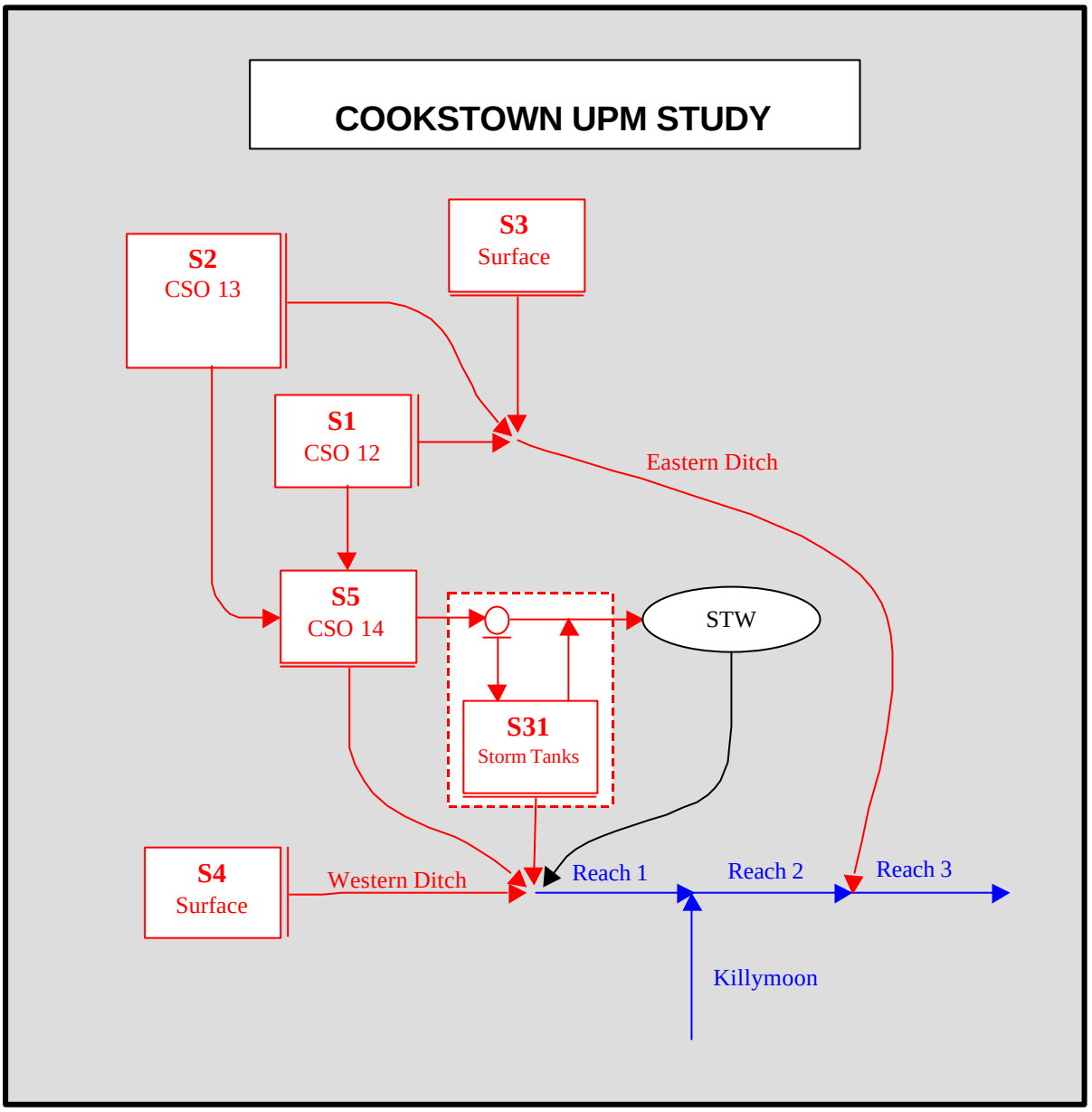

Figure 2 : SIMPOL Model Schematic

Task 4 : Running the SIMPOL Model – Generation of Baseline Results

Baseline results (see Table 3) for assessing compliance with the Fundamental Intermittent Standards for a Sustainable Salmonid Fishery study were generated by running the SIMPOLv2 model for the summer periods of the 10 years. This was achieved by dividing the 10 summers into 6,083 six hour time intervals. 827 of these time intervals were the rainfall events. The remainder were assumed to be dry. This form of analysis allowed the incidence of failures during dry weather periods as well as wet weather periods to be identified.

The conservative assumption was made that all storm events occurred when sewage base flows were at their largest and most concentrated, i.e. between 08.00 and 14.00 hours each day.

Dry Weather 525.6 six hr periods	DO			un NH3		
	1 year	3 month	1 month	1 year	3 month	1 month
Reach 1	0.0	0.0	0.0	0.2	0.3	1.6
Reach 2	0.0	0.6	1.6	0.0	0.1	0.3
Reach 3	0.0	0.2	1.0	0.0	0.1	0.5
Wet Weather 82.7 six hr periods	**DO**			**un NH3**		
	1 year	3 month	1 month	1 year	3 month	1 month
Reach 1	0.0	0.0	0.0	0.3	0.5	1.9
Reach 2	0.0	0.0	0.2	0.1	0.2	0.9
Reach 3	0.0	0.0	0.2	0.1	0.3	1.0
Total 608.3 six hr periods	**DO**			**un NH3**		
	1 year	3 month	1 month	1 year	3 month	1 month
Threshold (mg/l)	4.5	5.0	5.5	0.04	0.035	0.025
Permitted failures/yr	1	1.67	5	1	1.67	5
Reach 1	0.0	0.0	0.0	0.5	0.8	3.5
Reach 2	0.0	0.6	1.8	0.1	0.3	1.2
Reach 3	0.0	0.2	1.2	0.1	0.4	1.5

Achieves standard Fails standard

Table 3 : Baseline Results – Fundamental Intermittent Standards

The figures in the boxes in the table indicate the average number of 6-hour time blocks per summer for which the standards' threshold values were exceeded. Further results (not illustrated) were also generated to test compliance with the 1-hour FIS.

To test compliance against the GQA standards required consideration of the complete 10 year period, not just the summers. Results, shown in Table 4, were generated and presented in a similar manner to that described above, again based on 6-hour time blocks.

Dry Weather 1260 six hr periods	DO %sat 10%ile	BOD 90%ile	NH4 90%ile
Reach 1	49.6	123.4	39.3
Reach 2	46.6	100.0	39.4
Reach 3	57.0	98.0	38.6
Wet Weather 200 six hr periods	**DO %sat 10%ile**	**BOD 90%ile**	**NH4 90%ile**
Reach 1	8.9	43.9	26.9
Reach 2	8.4	30.7	16.7
Reach 3	8.9	32.6	16.8
Total 1460 six hr periods	**DO %sat 10%ile**	**BOD 90%ile**	**NH4 90%ile**
Threshold	70	4.0	0.6
Permitted failures/yr	146	146	146
Reach 1	58.5	167.3	66.2
Reach 2	55.0	130.7	56.1
Reach 3	65.9	130.6	55.4

Table 4 : Baseline Results – GQA Class B

Task 5 : Sensitivity Testing

The robustness of the baseline results to changes assumptions and input parameters was tested by an extensive programme of sensitivity testing. The following changes were investigated:

- Increased sediment quantities in the sewers (to high end of recommended range).
- Reduced erosion rates of sewer sediments (halved).
- Allowance for additional surface water runoff from new developments.
- Reduced in-river dissolved oxygen concentrations.
- Reductions in the quality and increases in the quantity of treated effluent from the proposed sewage treatment works.

The results for the sensitivity analysis are shown in Table 5.

		DO			un NH3		
		1 year	3 month	1 month	1 year	3 month	1 month
Threshold (mg/l)		4.5	5.0	5.5	0.04	0.035	0.025
Permitted failures/yr		1	1.67	5	1	1.67	5
R e a c h 1	Baseline	0.0	0.0	0.0	0.5	0.8	3.5
	DO 9mg/l	0.0	0.0	0.0	0.3	0.5	3.4
	DO 8mg/l	0.0	0.5	2.3	0.5	1.0	3.4
	Reduced erosion rate	0.0	0.0	0.0	0.5	0.7	3.6
	Increased sediment	0.0	0.0	0.0	0.6	1.2	3.6
	New development run-off	0.0	0.0	0.0	0.4	0.6	3.2
	Reduced effluent quality	0.0	0.0	0.0	0.7	1.0	4.6
	Effluent dwf 123 l/s	0.0	0.0	0.0	0.6	1.1	4.0
	Effluent dwf 150 l/s	0.0	0.0	0.0	0.97	1.65	6.6
R e a c h 2	Baseline	0.0	0.6	1.8	0.1	0.3	1.2
	DO 9mg/l	0.3	1.7	4.1	0.1	0.4	1.2
	DO 8mg/l	3.5	9.4	20.8	0.1	0.5	1.9
	Reduced erosion rate	0.0	0.6	1.8	0.1	0.3	1.1
	Increased sediment	0.0	0.6	1.8	0.1	0.4	1.2
	New development run-off	0.0	0.6	1.8	0.0	0.2	1.0
	Reduced effluent quality	0.2	0.5	0.9	0.1	0.3	1.4
	Effluent dwf 123 l/s	0.0	0.6	1.6	0.1	0.3	1.5
	Effluent dwf 150 l/s	0.2	0.2	1.0	0.2	0.6	2.8
R e a c h 3	Baseline	0.0	0.2	1.2	0.1	0.4	1.5
	DO 9mg/l	0.0	0.7	3.6	0.1	0.2	1.6
	DO 8mg/l	5.1	11.0	22.9	0.2	0.2	2.2
	Reduced erosion rate	0.0	0.3	1.2	0.1	0.3	1.6
	Increased sediment	0.0	0.3	1.4	0.1	0.4	1.6
	New development run-off	0.0	0.2	1.2	0.1	0.2	1.0
	Reduced effluent quality	0.2	0.3	1.1	0.1	0.4	1.8
	Effluent dwf 123 l/s	0.0	0.0	1.6	0.2	0.5	1.6
	Effluent dwf 150 l/s	0.2	0.2	2.0	0.3	0.5	2.8

Table 5 : Results of Sensitivity Analysis

Discussion of Results

The baseline results for the 6-hour FIS show no overall failures, suggesting robust compliance with standards for a Sustainable Salmonid Fishery following implementation of the proposed urban wastewater improvements. In general, the conditions in Reach 1 immediately downstream of the STW input are rather worse than the lower reaches where the diluting effect of the Killymoon River is present. Results for ammonia are distinctly worse than those for dissolved oxygen, suggesting that this is likely to be the controlling factor in the quality of

the Ballinderry River. The results also show poor river quality is more likely during wet weather, but can still occur during dry periods. However, neither occur frequently enough to threaten overall compliance.

The results for the 1-hour FIS (not shown) show even less incidences of failure than the 6-hour standards, although there is a change such that the greater number of failing time intervals are associated with dissolved oxygen rather than ammonia. Overall, this set of results show that the shorter time interval standards are not critical for this particular catchment.

Table 4 shows that threshold failures of the GQA Standards are more common and that there is an overall marginal non-compliance in Reach 1 for BOD. However, the results also show that failures are just as likely to occur in dry weather as during wet periods, suggesting that the problem, if it exists, is associated with the background conditions in the river and/or the quality of the STW effluent. In this context, it should be noted that the STW was modelled as operating at the upper limit of its registered consent conditions which is a conservative assumption. This phenomenon was investigated further during the sensitivity testing.

In general terms, the results of the sensitivity testing programme show that the principal conclusions drawn from the base line results are extremely robust. The only significant failures induced during the sensitivity testing occurred when parameters such as in-river mixed dissolved oxygen were ascribed values which were beyond the bounds of what could be considered reasonable.

Conclusions

The major conclusion of the Cookstown UPM study is that the proposed improvements to the urban wastewater system of Cookstown will definitely support the achievement of the long term river quality objectives for the Ballinderry River in terms of both the FIS and GQA standards.

In addition, it has been shown that the retention of the three CSOs towards the bottom end of the sewer system is acceptable in environmental terms provided that they are upgraded in the required manner incorporating storage and appropriate screens.

More broadly, the project has demonstrated that it is possible to carry out a study:

- to test compliance of urban wastewater upgrading proposals with a wide range of environmental standards at moderate cost;
- to undertake such studies using data that are commonly already available, avoiding the need for expensive field data collection exercises;
- generate reliable and robust results in which it is possible to have a high level of confidence.

References

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