STOKE UPM STUDY – A COMPREHENSIVE SOLUTION

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Introduction

The city of Stoke-on-Trent and town of Newcastle under Lyme, which lie within the same natural and manmade catchment serving the River Trent, are located to the north of the Severn Trent Midlands region in North Staffordshire. The urban conurbation has a population of approximately 322,500 and is situated at the head of the River Trent catchment where river flows are relatively low.

The watercourses in the Stoke catchment are small and as industry has declined, the significance of sewage related discharges to the watercourses have become greater. The Environment Agency has identified long-term river water quality problems in the catchment. Intermittent discharges from the Stoke combined sewer system contribute to quality problems in the River Trent and its tributaries in times of storm and this issue has been raised by the Environment Agency for rectification during the AMP 3 Programme.

The large number of unsatisfactory overflows in Stoke and sensitive rivers with low base flows make the traditional approach of providing Scottish paper requirements inappropriate. These require too much storage in some circumstances due to double counting of contributing populations and too little in others due to sensitive receiving watercourse quality. Consequently Severn Trent Water Ltd commissioned Haswell Consulting Engineers to undertake an Urban Pollution Management (UPM) study of the catchment. Urban Pollution Management techniques give a framework within which catchment wide intermittent water quality problems can be examined in a holistic manner.

This paper describes the process that was adopted and the comprehensive solution that has been developed to relieve 54 unsatisfactory intermittent discharges in the catchment by the end of the AMP 3 period.

Catchment Details

Sewerage Systems*:* The sewerage system serving Stoke and Newcastle is largely combined in nature and is shown in outline in **Figure 1**. Of particular note is that the Western part of the catchment drains to a large terminal pumping station at Trent Vale, which then pumps flows to Strongford works. The Eastern part of the catchment drains to the works by gravity. There are major storm tanks at both Trent Vale and Strongford.

The sewerage system is complex and has a total length of over 1,500km. The considerable size and steepness of the catchment causes the time of concentration in both the river and the sewerage system to vary spatially across the catchment. Furthermore the time of concentration at the head of the catchment is shorter in the sewer than the river system, whereas in the smaller reaches this condition is reversed and the time of concentration becomes lower in the river. Consequently CSOs have a large impact on the Stoke river system in times of storm and many of the existing overflows have little storage or screening incorporated in the design.

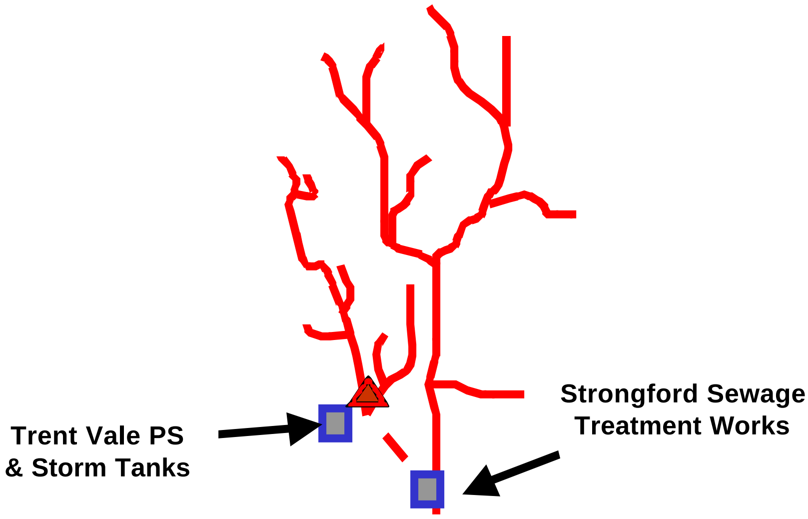


Figure 1. Outline of sewerage system serving Stoke and Newcastle

Severn Trent Water Ltd's predecessors and latterly Severn Trent itself adopted a process of rationalising Sewage Treatment Works in the catchment over several decades, driven by financial efficiencies and river water quality improvements. The rationalisation process is shown in **Figure 2**. As a result of this a single works at Strongford now serves the entire urban catchment and discharges to the River Trent downstream of the Stoke conurbation.

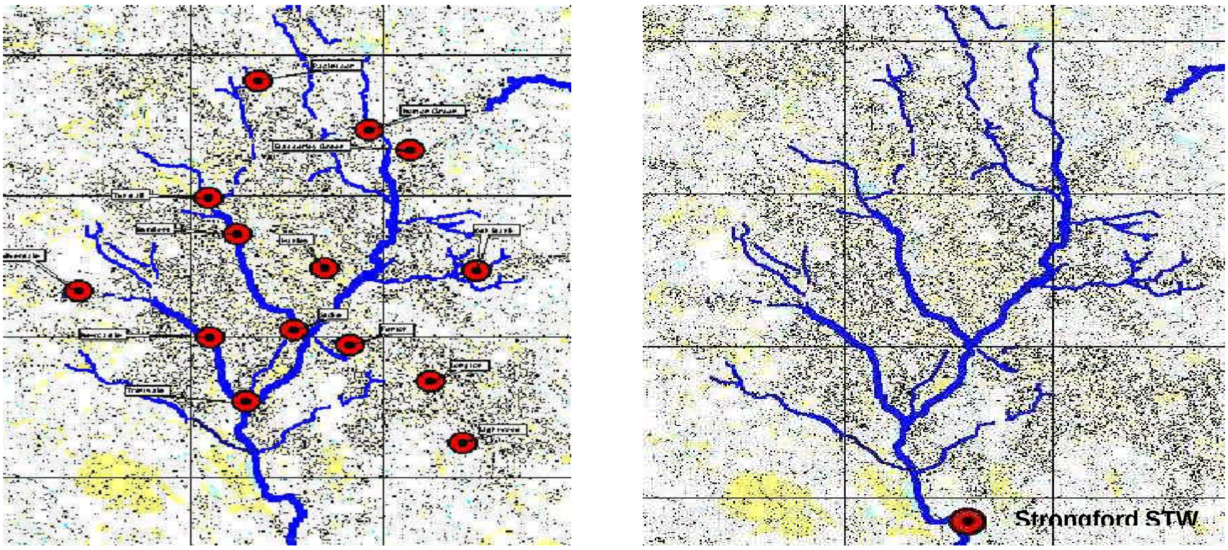


Figure 2. Rationalisation of sewage treatment in the catchment showing sewage treatment works and river systems. Left - circa 1935. Right - present day single works at Strongford

There are 135 known Combined Sewer Overflows (CSOs) in the study catchment, partly as a result of this rationalisation in sewage treatment provision and these are illustrated in terms of location relative to the catchment and magnitude in **Figure 3**. Of these Severn Trent Water Ltd and the Environment Agency (through their 1997 LEAP Report and detailed FR 0466 survey) have identified 54 intermittent discharges from the water company assets that are believed to cause unacceptable pollution to the receiving watercourses and must be addressed in the AMP3 period. Severn Trent Water Ltd opted to use the UPM methodology to improve these overflows and to achieve the greatest environmental benefit with the available funding, in a way that will complement future investments. The approach takes full account of the receiving waters both in terms of their desired quality and their users.

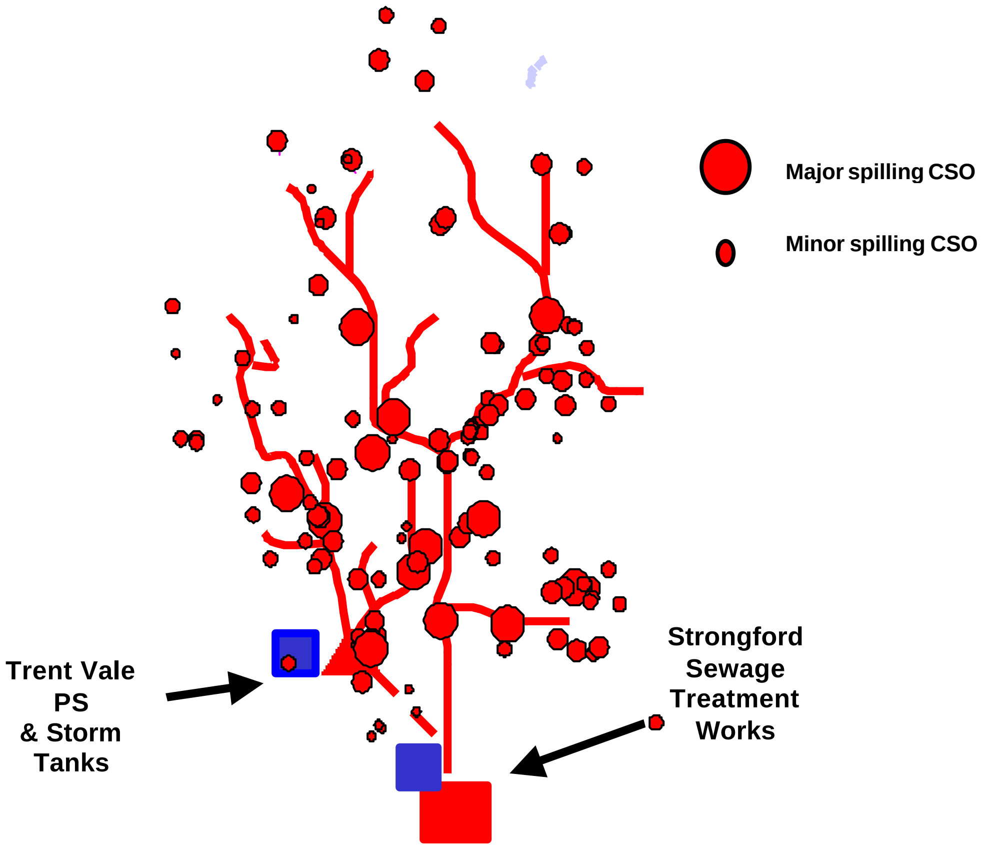


Figure 3. 135 CSOs located in catchment. The size of circle gives an indication of significance

River Systems: The Stoke and Newcastle area is located at the head of the River Trent catchment and therefore river flows are low. The principal watercourse is the River Trent with significant inputs from the Ford Green Brook, Causeley Brook and Fowlea Brook, which itself receives flows from the Scotia Brook. The Lyme Brook joins downstream of the Fowlea Brook and further downstream are the Longton and Park Brook inputs, only a little way upstream of Strongford Sewage Treatment Works. Downstream of its outfall point the Strongford works has a major influence on the River Trent contributing approximately two thirds of river flow. The Environment Agency River Quality Objectives for these watercourses are shown below in **Figure 4.**

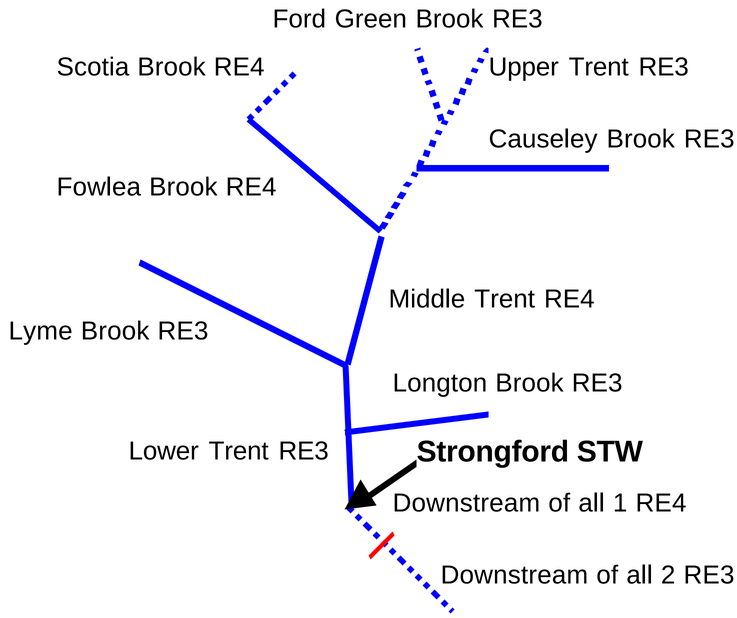


Figure 4. EA River Quality Objectives used in the SIMPOL model. Reaches failing RQOs shown thus:

The City of Stoke-on-Trent are planning to open up some of the watercourses in the city by introducing new river walkways to make better use of this important natural amenity. Aesthetic pollution from CSOs is particularly undesirable in public amenity areas, and with the increased use of the Stoke river system this issue reinforces the need for CSO improvement works. There has been considerable interest by MPs in the catchment and publicity relating to the aesthetic problems caused by CSOs in the catchment.

The chemical quality reported as GQA scores for 1997 indicates that the water quality for the River Trent is fair to fairly good from its source down to Stone. The quality of the brooks is variable with the quality of the Fowlea Brook as poor and the Lyme Brook reported as good.

This is not reflected in the biological quality of the river. The biological quality reported as GQA scores for 1997 indicates that the water quality of the River Trent deteriorates from good to fairly good between the source and Abbey Hulton and then deteriorates to poor and bad quality through Stoke. The quality of the brooks is equally disappointing, with the quality of the Longton Brook, Causley Brook, Scotia Brook as bad, the Lyme Brook and Fowlea Brook are both reported as being poor quality.

This mismatch between the chemical and biological quality in these watercourses suggested significant effects from intermittent pollutant sources. For this reason the study was required to derive solutions that would demonstrate compliance with both Fundamental Intermittent Standards (FIS) and 99 percentile standards.

Sewage Treatment**:** The population of Stoke-on-Trent and Newcastle-under-Lyme was, until the mid-seventies, served by five principal works at Tunstall, Burslem, Hanley, Strongford and Checkley. Minor works were located at Fenton, Ash Bank, Norton Green and Baddeley Green. Strongford was always the logical location for a scheme of centralised sewage disposal, and extensions in the mid-seventies permitted the progressive closure of works at Hanley, Fenton, Ash Bank, Norton Green and Baddeley Green. Early in 1988 Tunstall S.T.W. was closed and the sewage flow diverted to Burslem S.T.W. In 1991/92 a link sewer scheme was undertaken and all flows from the Burslem catchment were diverted to Strongford.

The population served by Strongford is now approximately 322,500 with a dry weather flow of 115M.l/day (1,331 l/s). Flow to full treatment is 236 Ml/day (2,731 l/s). These flows are significantly larger than the mean dry weather flow of 370 l/s in the River Trent immediately upstream of Strongford. The impact of the works upon the river is therefore highly significant.

Incoming flows of less than 2,731 l/s arriving at the inlet chamber pass through to full treatment, whereas flows in excess of this limit overflow to storm tanks. The storm tanks at the works are sized to hold a volume of 24,649m^3 before spilling to the River Trent. When storm flows have subsided the tanks are emptied by a pump return, which discharges back to flow to full treatment. It is known that flows to Strongford remain high for some time after the peak of a storm as the catchment drains to the works. This means that the storm tanks often remain full for some time and can continue to spill after a storm has passed. This is exacerbated by practical difficulties in emptying the tanks.

Objectives of the UPM Study

The specific objectives of the Stoke UPM study were to:

- Provide a statement of current knowledge about the system.
- Gain a better understanding of the interactions between the sewerage, sewage treatment and river systems.

- Establish the current performance of the system to validate the modelling tools developed.
- Develop a strategy to address the UIDs using the modelling tools in line with the UPM methodology as a basis for feasibility work on individual schemes.

In addition, the Study needed to ensure that in the formation of a strategy to implement these improvements from notional schemes to completed engineering projects, the following areas were addressed:

- Ensure that improvements are quantifiable (River Quality Before Vs. River Quality After).
- Ensure that improvements are based on robust planning methods.
- Develop an Investment Strategy for AMP3 in the City that minimises expenditure by providing the required environmental benefits at least cost.
- Maintain Environment Agency approval for strategy and schemes as they progress, to permit smooth consent application and issue.
- Timing in the AMP period and how Capital Schemes will be fed by Urban Pollution Management findings.
- Development of a Phased Construction Programme for a possible 54 capital schemes to be delivered before March 2005.

Study Process Adopted

The Study was conducted in two stages. Firstly a scoping study was undertaken to gather all available data on the sewer, river and sewage treatment systems. This allowed an overview of the catchment needs to be taken, assisted by a coarse SIMPOL model, which was built and used to test the sensitivity of the watercourses to wet weather events. It also acted as a Forum with which to bring together the main stakeholders. The conclusion was that a second stage of the Study in the form of a detailed UPM was needed to satisfy the Objectives and derive cost effective improvements to the river system and sewerage system operation alike.

The detailed study comprised the following key elements:

1. Compilation of a detailed hydraulic model of the catchment in InfoWorks bringing together models from the 8 Drainage Areas that form the Stoke and Newcastle Catchments.
2. Construction of a detailed model of the River Trent using MIKE 11.
3. Construction of a process model of the Strongford Sewage treatment Works using GPS-X.
4. Construction of a simplified river impact model using the SIMPOL version 2 software.
5. Selection of rainfall and generation of storm data using STORMPAC version 2 software for simulation, based on actual catchment parameters over the preceding 20-year period.
6. Comprehensive data collection for flow and quality in all three systems for Summer and Winter using in-situ monitors and loggers, physical surveys including dye dispersion surveys and continuous water quality sampling provided by the Environment Agency.

The Study followed the iterative planning approach, which is discussed in the UPM manual Section 3.6. The upper section of the urban catchment was classified as steep catchment and a population equivalent of more than 20,000. Simple impact modelling with default values was identified as the modelling tool for the Stoke UPM study in order to generate a solution that complies with all standards. By choosing the necessary impact modelling this allowed the planning study to move forward and generate a potential solution as rapidly as possible, in line with the UPM procedure.

The Study process in its simplified form then comprised verification of the detailed dynamic models of the sewerage system, rivers and sewage treatment works. These were then in turn used to calibrate the simplified river impact model to a point where the SIMPOL model outputs gave a high degree of correlation with the detailed models for the existing systems, both in terms of hydraulic and water quality. Once a good degree of correlation was achieved for the existing performance of each watercourse this could then be compared with the target performance for each reach. The overall biological river quality objective for the watercourses was established by the Environment Agency as Sustainable Cyprinid and the SIMPOL results for the existing configuration together with the respective target and actual simulated RQO's are illustrated below in **Table 1:**

Performance against standards	99%ile for RQO			FIS sustainable cyprinid fishery				RQO for reach	Simpol RQO met
	BOD	TotNH3	UnNH3	DO 1yr	DO 1m	UnNH3 1y	UnNH3 1m		
No. of failures permitted per year (see Table 2.4 for	14.6	14.6	14.6	1	12	1	12		
Causeley Brook	F (26.4)	P (0)	P (1.75)	P (0)	P (0)	P (0)	P (0)	3	5
Lyme Brook	F (30.6)	P (0.15)	P (5.65)	P (0.1)	P (0.7)	P (0.1)	P (0.2)	3	5
Longton Brook	F (37.75)	P (1.8)	P (14.2)	P (0)	P (0.1)	P (0)	P (0.3)	3	4
Scotia Brook	F (59.55)	F (39.15)	-	F (1.7)	P (7)	P (0)	P (3.9)	4	>5
Fowlea Brook	F (48.3)	P (2.65)	-	F (1.5)	P (4.6)	P (0.3)	P (2.8)	4	<5
Upper Trent 1	P (1.4)	P (0)	P (0)	P (0.1)	P (0.6)	P (0)	P (0)	3	1
Upper Trent 2	F (31.55)	P (0)	P (3.65)	P (0.1)	P (0.3)	P (0)	P (0.1)	3	<5
Upper Trent 3	F (26.6)	P (0)	P (0.45)	P (0)	P (0)	P (0)	P (0)	3	5
Middle Trent	F (26.5)	P (0)	-	P (0.1)	P (0.1)	P (0)	P (0.1)	4	5
Lower Trent 1	F (59.8)	F (19.4)	F (32.05)	P (0.2)	P (0.5)	P (0.1)	P (4.5)	3	<5
Lower Trent 2	F (60.95)	F (26.1)	F (21.85)	P (0.9)	P (2.8)	P (0.1)	P (5.2)	3	<5
DS of All 1 (3km)	F (35.55)	P (0)	-	F (4.4)	P (10.5)	P (0.9)	P (1.9)	4	5
DS of All 2 (3km)	F (48.3)	F (26.15)	F (26.65)	F (11.2)	F (20.3)	F (3.1)	P (9.6)	3	<5
Ford Green Brook	See separate Table further analysis								
DS of All 6km - No longer included	F (63)	F (43.15)	F (16.7)	F (46.5)	F (54.6)	F (31.3)	F (36.9)	3	>5

Table 1: Compliance with UPM Standards using 20 years of rainfall data processed through STORMPAC (1419 storms)

As can be seen all of the brooks except Scotia Brook are failing the 99%ile standard. SIMPOL predicts that the Scotia Brook will fail both 99%ile and FIS standards under the existing system scenario. Upper Trent 1 is predicted to meet RE1 classification and to pass both water quality standards. However, all River Trent sub-reaches (except Upper Trent 1) are either failing 99%ile standard and/or FIS.

Development of Solutions

The focus for the development of solutions has been on placing additional storage in the SIMPOL model to reduce the spill frequencies and volumes in order to bring about the resultant improvement in the quality of receiving watercourses. Within SIMPOL this gives a resultant spill reduction that is then replicated in the detailed models as part of the detailed solution development. The detailed models are then manipulated to achieve this spill reduction, whether by storage, increased pass forward flow or flow transfer. Where feasibility study shows it to be practical and economical to remove storm flow from the combined sewer through separation or rehabilitation this is being considered.

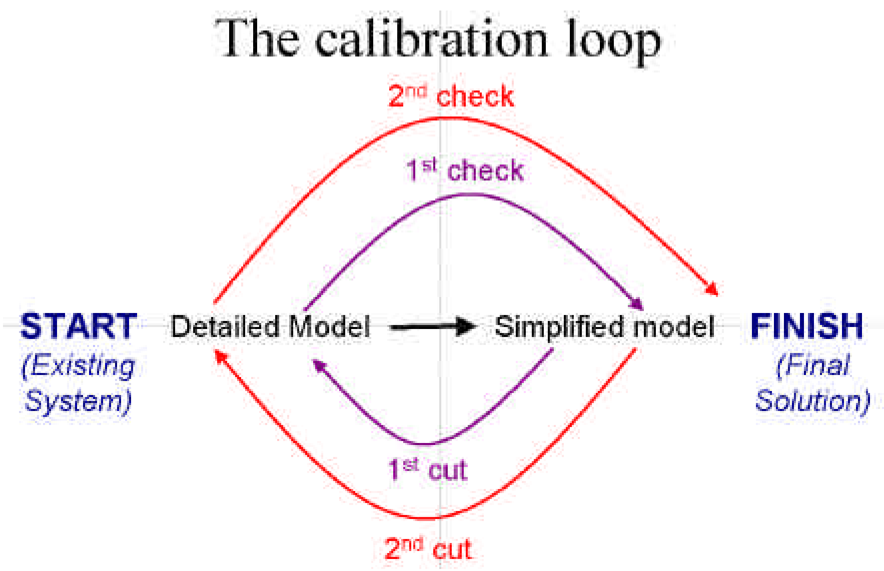
Placing the additional storage in the system has been based on the following approach:

- The SIMPOL model was used to inform an initial distribution of additional storage

- Where there was a choice to add storage to one catchment or another, the focus was on placing it where schemes were likely to be required to target ‘big-spillers’ or frequent spillers.
- Once the rivers were all brought to a point that they passed the quality standards the storage locations and volumes were tuned back to arrive at an optimal situation.

An iterative process was adopted as illustrated in **Figure 5** taking into account the following criteria:

1. It is more economical to construct storage upstream within the catchment and where possible local to the target CSO/UID
2. The frequent spillers and the big spillers should receive priority when assessing where to place storage
3. As a first phase solution, assess the catchment working from the top to the bottom
4. Be aware that upstream reaches may require “over improvement” in order for required standards in the down stream reaches to be achieved
5. Recalibrate the SIMPOL model in turn to suit the solutions as they are developed



The solutions developed were primarily required to address the water quality problems within the Stoke catchment. However, the solutions were also tested to ensure that flood risk standards were met. Aesthetic and operational issues will be addressed through later feasibility work. This process of refining the options could clearly go on sometime to arrive at a yet more optimal solution. However, it is considered that within this study a combination of solutions have been developed which, given the parameters used, arrive at a river system passing the River Quality Objectives, and that this has been achieved using a significantly lower storage volume than that indicated by empirical methods. Not only is the volume less but the model has targeted the storage where most required.

The solutions required to be implemented using the traditional Scottish Paper Storage approach using the DAS models developed before the Stoke UPM was undertaken would have required a total storage volume to be constructed within the catchment of **23,922m^3**

The notional schemes developed using the above iterative approach and the UPM methodology achieve the required river quality objectives with a greatly reduced total storage volume of **13,825m³**

The table below shows greatly improved water quality within each river reach once appropriate storage is added to each sub-catchment. The majority of all river reaches are now passing both the 99 percentile for River Quality Objectives and the Fundamental Intermittent Standards for the Sustainable Cyprinid Fishery. However, Downstream of all 2 is still failing both standards and has been agreed as the subject of further study as the solutions are developed in detail.

Performance against standards	99%ile for ROO			FIS sustainable cyprinid fishery				ROO for reach	Simpol ROO met
	BOD	TotNH3	UnNH3	DO 1yr	DO 1m	UnNH3 1yr	UnNH3 1m		
No. of failures permitted per year (see Table 2.4 for	14.6	14.6	14.6	1	12	1	12		
Causeley Brook	P (14.55)	P (0)	P (2.55)	P (0)	P (0)	P (0)	P (0)	3	3
Lyme Brook	P (9.25)	P (0)	P (0.1)	P (0.1)	P (0.4)	P (0)	P (0)	3	2
Longton Brook	P (13.55)	P (0)	P (2.5)	P (0)	P (0)	P (0)	P (0)	3	3
Scotia Brook	P (13.65)	P (4.1)	-	P (1)	P (3.5)	P (0)	P (0.1)	4	3
Fowlea Brook	P (12.9)	P (0)	-	P (0.5)	P (2)	P (0)	P (0)	4	4
Upper Trent 1	P (1.6)	P (0)	P (0)	P (0.1)	P (0.8)	P (0)	P (0)	3	1
Upper Trent 2	P (10.45)	P (0)	P (0.55)	P (0.1)	P (0.3)	P (0)	P (0)	3	1
Upper Trent 3	P (9.2)	P (0)	P (0.1)	P (0)	P (0)	P (0)	P (0)	3	1
Middle Trent	P (8.3)	P (0)	-	P (0)	P (0.3)	P (0)	P (0)	4	2
Lower Trent 1	P (11.75)	P (0)	P (0.45)	P (0.1)	P (0.4)	P (0)	P (0)	3	2
Lower Trent 2	P (12.85)	P (0)	P (1.05)	P (0.2)	P (0.5)	P (0)	P (0)	3	3
DS of All 1 (3km)	P (6.8)	P (0)	-	P (0.8)	P (3.5)	P (0.1)	P (0.4)	4	3
DS of All 2 (3km)	F (15.65)	P (9.7)	P (11.1)	F (2)	P (5.1)	P (0.3)	P (2.1)	3	4

Table 2: SIMPOL results with Notional Schemes using 20 years of rainfall data processed through STORMPAC (1419 storms)

The Notional Schemes are currently being developed into 32 separate schemes and these will be constructed over the remaining three years of AMP3. These are illustrated in **Figure 6** below:

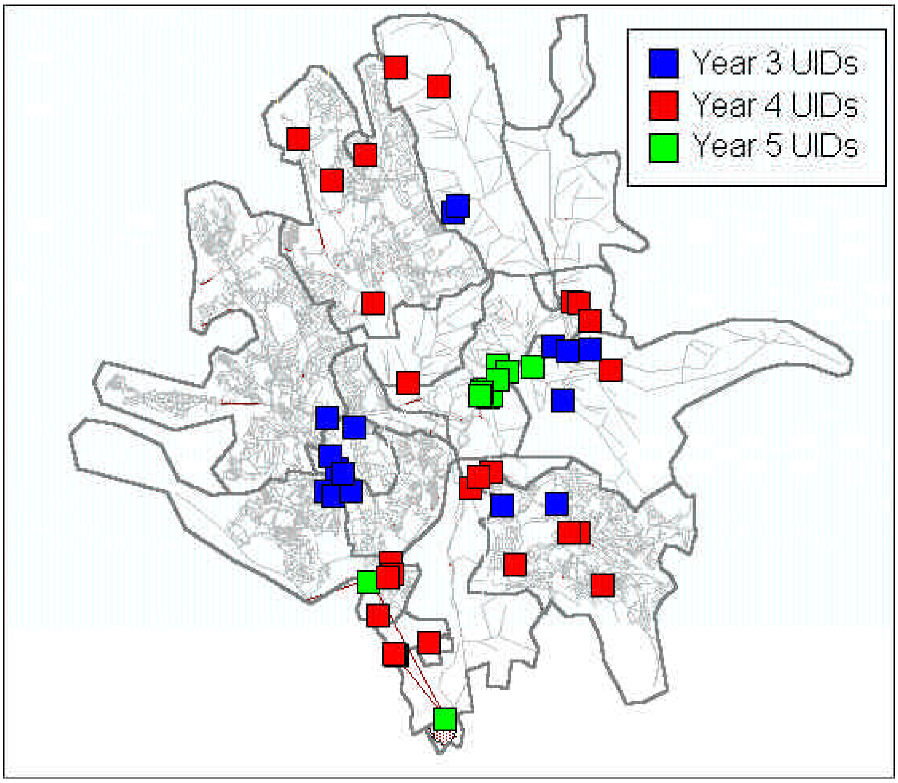


Figure 6: Scheme Delivery – Years 3, 4 and 5

Solution Type	**Percentage of UIDs addressed using this solution type**
Abandonment/Rationalisation	20%
CSO chamber rebuild and screen provision	40%
Utilisation of existing system storage	10%
Storage on line	10%
Storage off line	15%
Pumping Station Rebuild and Storage	5%
New Treatment Works	0

Typically the solutions developed comprise a mix of techniques and fall roughly into the following categories:

Construction of new treatment works in the catchment was considered but in view of the available solutions was found not to be cost effective.

Conclusions

The SIMPOL model has been used in conjunction with the detailed models to develop an improvement strategy using an optimised volume of additional storage in the sewerage system to improve river quality. The optimum combination of solutions developed from the Stoke UPM study proposes the use of 13,825m^3 of storage distributed at UIDs throughout the study area together with improvements at Trent Vale pumping station and Strongford storm tanks. This storage volume, and the capital investment it represents, compares with an original volume of 23,922m^3 developed from empirical methods and therefore fully justifies the investment in the UPM study.

Scheme feasibility has been developed in parallel with this study using output from the previous SIMPOL model. Schemes to address 16 UIDs have been developed for Year 3 (commissioning March 2003) and a further 22 UIDs have been identified for Year 4 (commissioning March 2004). The remainder are addressed in Year 5. All models allow for proposed new trade discharges. The sewer solution strategy for Stoke also incorporates an additional 6 Nr CSOs in addition to the named 54 Nr UIDs. These are also being reviewed in the SIMPOL model.

A number of interesting constraints and procedures have arisen as the Study has developed. In particular it has been found necessary to exchange or “swap” UIDs and CSOs in places where the significant spilling CSOs have been found to be different from those identified at the start of AMP 3. These have arisen where CSOs have had common outfalls, where the outfalls were inaccessible at the time of survey or the CSOs have been found to be sensitive to particular storm events. Any such exchanges have had to be agreed under the ‘National

Change Procedure', which requires ministerial consent. This process has required close work with the Environment Agency and Severn Trent in order to achieve the desired result.

It is in this area in particular that the UPM approach gives the greatest benefit. By taking a catchment wide view it is possible to take account of particular sub-catchment characteristics and optimise storage to achieve the required RQOs. However the refinements arising whilst progressing scheme feasibility in parallel with the UPM development can lead to difficult programming changes in order to meet expenditure profiles and benefit delivery and so the skills of the project manager are still a major part of the process.

Acknowledgements

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