APPLICATIONS OF STORMPAC AND SIMPOL

D. Wotherspoon*, M. Petrie*, G. Stenhouse* and R. Crabtree†
*North of Scotland Water Authority (Tel 01382 563100)
† WRc plc (Tel 01793 511711)

Summary

This paper highlights the use of historical rainfall analysis and simplified sewerage system models in the analysis of options for improvements for sewerage systems. The paper is not meant to be an exhaustive discussion of the merits of any particular software packages, but aims to raise the awareness of these two particular elements as part of the initial planning process in drainage design.

Keywords

Rainfall analysis, STORMPAC, SIMPOL, simplified urban pollution modelling, HYDROWORKS, Urban Pollution Management

Introduction

The publication of the Urban Pollution Management (UPM) Manual in 1994 brought to the attention of the practising Engineer the wide range of tools available for the analysis of urban sewerage systems. The Tayside Regional Office of the North of Scotland Water Authority, through its predecessor, Tayside Regional Council Water Services Department have been involved in a number of UPM investigations in conjunction with both the WRc and the University of Abertay Dundee (UoAD). The sewerage system in the City of Perth has served as the basis for early trials of modelling tools including MOSQITO, HYDROWORKS QM and STOAT. The data collected for these studies will also shortly be used for an application of MOUSETRAP. This paper specifically refers to two further UPM tools which have been utilised in the analysis of sewerage systems in the area: STORMPAC and SIMPOL.

The Perth Drainage Catchment

The sewerage system of Perth serves a population of approximately 42,000 and drains an area of around 15 km^2. The sewerage system is mainly combined with peripheral areas consisting of separate and partially separate systems. There are three pumping stations associated with the drainage system; South Inch, Friarton and Willowgate. The latter station is a small package plant, whilst the remaining pumping stations consist of archimedes screws which operate to allow gravitational flow to the wastewater treatment plant (WTP) at Sleepless Inch. The WTP is an activated sludge plant with consent standards limited to 100mg/l for BOD and TSS.

Potential Wet Weather Problems

In the Bridgend catchment, six overflows discharge to the River Tay. Although the River Tay itself has a very high mean flow (74 m^3/s during summer and 300 m^3/s during winter), these overflows discharge into side channels with a relatively low flow, leaving evidence of visual pollution. Five unscreened "hole in the wall" type overflows also discharge to the Craigie Burn in the Craigie catchment. The principal controls on the sewerage system are the South Inch and

Friarton Pumping Stations. Both stations have screened overflows set at relatively low levels discharging to the River Tay via flap valves. Both overflows spill significant volumes to the River Tay.

Rainfall Inputs

Design storms were not applicable to the problem to be addressed, i.e. assessment of spill frequencies and discharges from storms of very much less than a one year return period. The annual Time Series Rainfall (TSR) was predominantly developed for regional areas in England and application to Scottish regions via the relatively crude regionalisation procedures has been treated with caution. Hourly rainfall information was available from the Meteorological Station at Leuchars, some 25 miles to the south-east of Perth. The application of this data through a "Method 1" analysis was considered. However, previous trials of this data with catchments in Dundee and comparison to local daily recorded data indicated that significant differences could occur. It was therefore decided to utilise local daily rainfall information from Perth, as far as possible, and test the STORMPAC software against this data and local daily data at various sites throughout the region. The results are given in Table 1 below.

Table 1 - Comparison of monthly average rainfall

	Dundee Clatto Data	STORMPAC	Arbroath Data	STORMPAC	Perth Data	STORMPAC
Jan	81.5	81.5	55.1	61.3	86.1	96.0
Feb	58.6	61.7	39	40.7	52.4	49.1
March	70.2	59.7	44.5	42.4	65.6	60.3
April	48.2	45.3	38.1	36.1	41.6	44.2
May	49.5	52.9	51.9	60.9	47.4	45.7
June	58.1	64.7	46	41.9	57.5	63.1
July	57.2	54.7	54	51.5	58.1	50.3
August	68.8	61.7	66.9	64.9	63.6	69.6
Sept	84.3	85.1	62	58.5	67.4	69.5
Oct	85.7	86.7	57.5	63.7	74.2	69.2
Nov	67.3	74.0	55.6	57.5	66.5	64.5
Dec	74.5	70.3	51.4	59.1	73.9	77.6
Annual Total	803.9	798.1	622.0	638.6	754.3	759.1

The sites examined ranged from coastal locations (Arbroath) through to inland locations (Perth). Data were also analysed from Montrose and Forfar. All generated data compares well with the published data at the various locations. STORMPAC can utilise daily rainfall information or daily mean values (from monthly averages). The STORMPAC manual recommends that daily information is used if it is available. Although daily data were available for many of the areas, from the Authority's own raingauges, the STORMPAC simulation was **found to represent the monthly averages equally well with monthly published totals as daily data.** A further check was made on the distribution of events within the synthetic series, by comparing it with the daily rainfall totals for Perth across a range of total depths.

Table 2 - Distribution of rainfall daily total depths (% of total number of events)

Daily total depth	<3mm	3 to 10 mm	10 to 15 mm	>15mm
Perth Data	78.6	15.9	2.9	2.6
STORMPAC	78.5	17.0	2.7	1.8

The synthetic series appeared to underpredict the number of larger storm events when compared to the recorded daily totals. This test was carried out with version 1.2 of STORMPAC which can reproduce the statistical characteristics of up to a 2 year return period. The data produced for the various sites appear to be satisfactory and the Regional Office of the Authority intend to continue to use historical rainfall analysis using the STORMPAC software. The next release is intended to extend the range up to a 10 year return period. A minimum data requirement of monthly totals from local raingauges is recommended. It has not been possible to test the disaggregation routine against recorded local data.

Sewerage System Analysis using SIMPOL

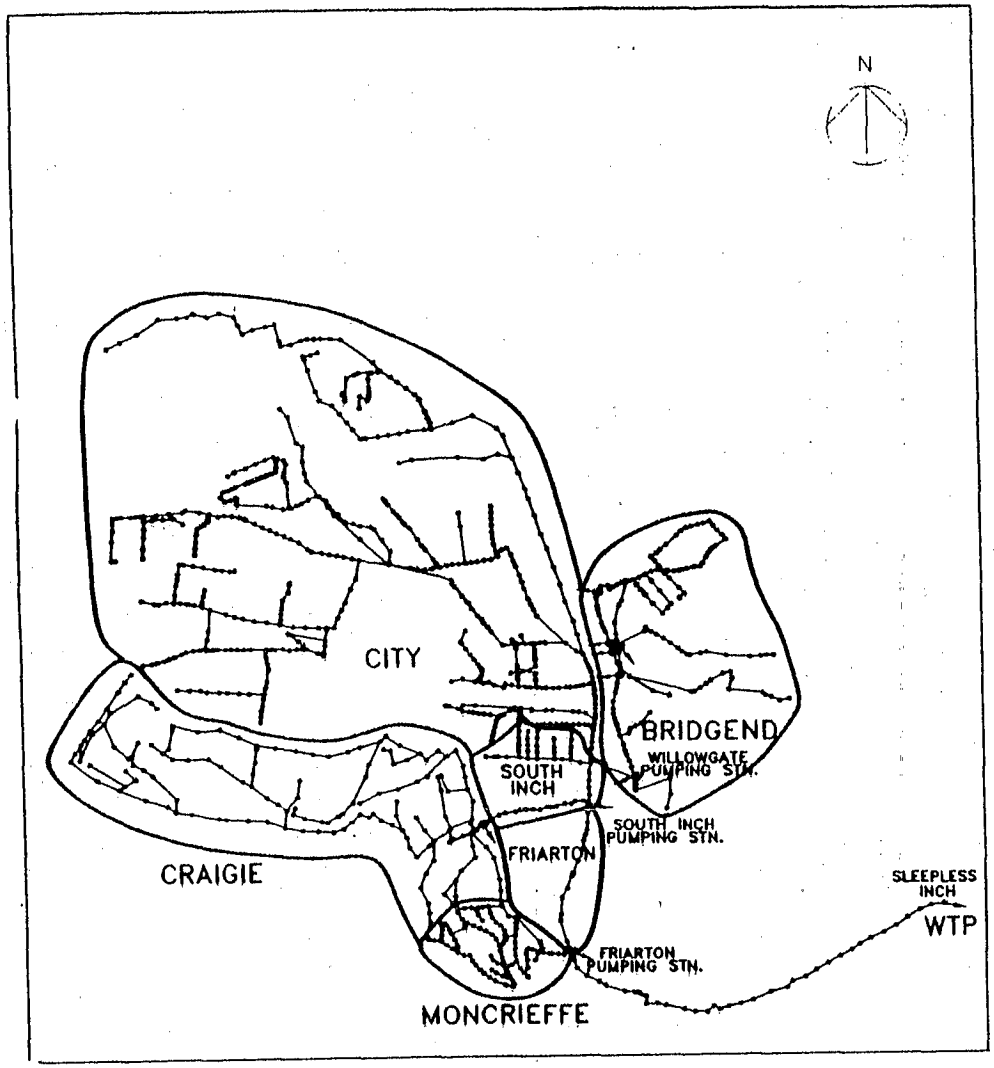
A number of sewerage system models have been built in the Tayside area in recent years, predominantly to assist in planning for the implementation of the UWWTD. Much of this planning is concerned with spill frequency analysis for CSO discharges and stormwater storage volume assessment. A number of available techniques have been utilised and their relative merits have been assessed.

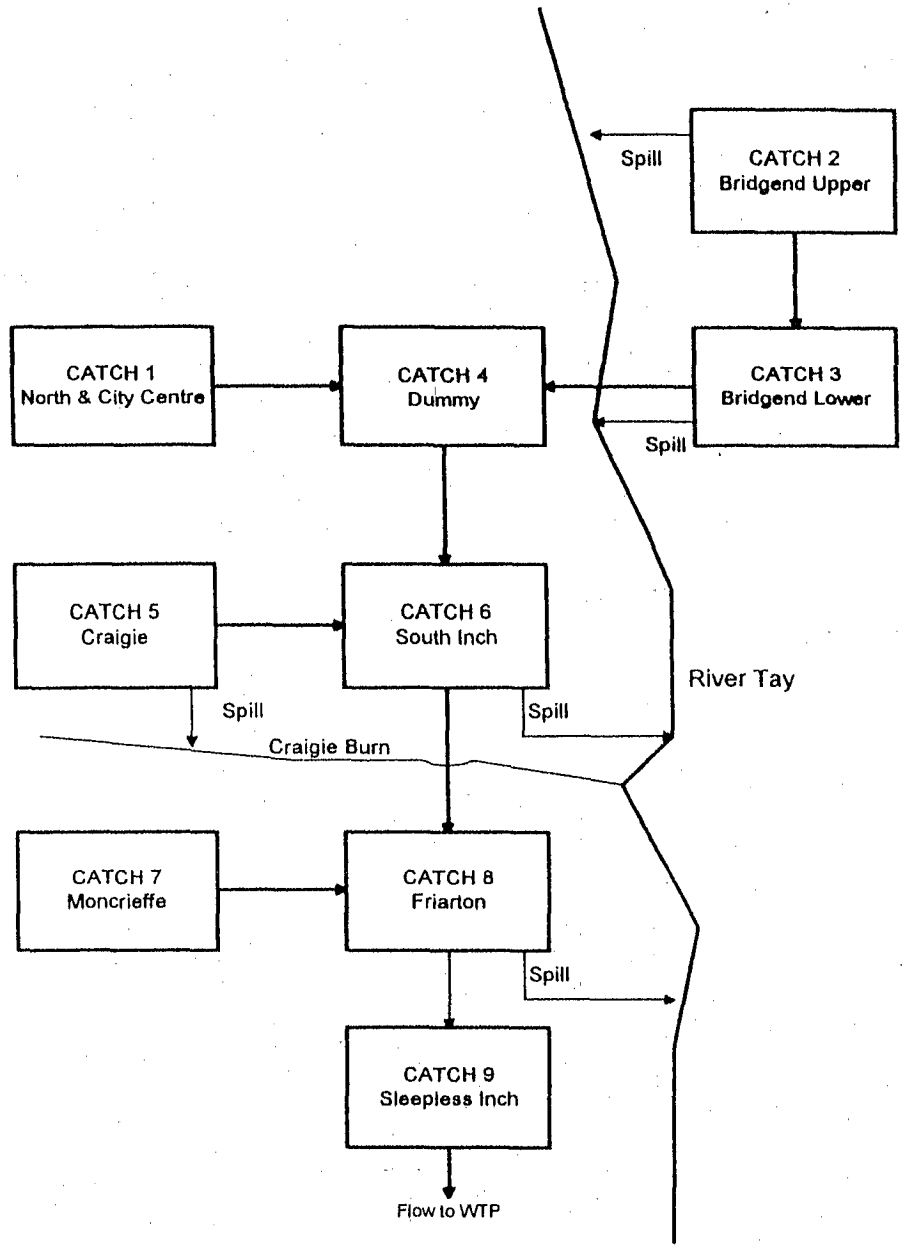
The approach taken by the Authority is that sewerage system models for populations of greater than 10,000 are generally developed using HYDROWORKS to a Drainage Area Planning standard. The detailed HYDROWORKS model is then used to calibrate any simpler model (SIMPOL) or used directly with rainfall data (e.g. Method 1 analysis). SIMPOL has been used for purely hydraulic analysis on two major catchments in Dundee, Perth and the town of Arbroath. In each case, it has been possible to construct and calibrate a SIMPOL model very quickly and utilise the full ten to twenty years of generated synthetic rainfall from STORMPAC to produce long term spill frequencies and stormwater storage volumes. The key elements required for the SIMPOL spreadsheet are adequately described in the UPM Manual.

The representation of the catchment is the most crucial part of the simplification process. The location of any CSOs to be represented will already be known. A design storm run through the HYDROWORKS model will assist in identifying the key throttle points within subcatchments. The choice of calibration storms may either be on a selection from a ranking of the STORMPAC events or the uncalibrated SIMPOL model may be used to assess likely key events. A minimum of ten events, with varying UCWI, intensities and durations is required to obtain confidence in the calibration.

The validity of the SIMPOL method has been tested in certain areas by comparing the results obtained against results from other methods of analysis. In the case of Perth, a Method One analysis had previously been carried out with a regionalised rainfall data set from Leuchars. This produced an annual spill volume estimate from the South Inch pumping station of some 230,000m^3. The SIMPOL analysis with a synthetic series resulted in an volume of 252,000m^3 (within 10% of the former analysis). In Dundee, an analysis of the Dighty catchment serving the north-east side of the City indicated a stormwater storage requirement of 16,000m^3 for a one spill per summer rule at a specific location, whilst a more time-consuming analysis using the detailed HYDROWORKS model of the catchment suggested 15,600m^3. These two examples serve to demonstrate that any concern regarding loss in accuracy due to the use of the

SIMPOL Representation of Perth Catchment





simplified hydraulics has not been proven. The ability to consider all rainfall events required and the variability of these events, rather than a selected grouping provides a demonstrable improvement in predictive capabilities.

The main benefit of SIMPOL is the speed at which simulations may be performed. Various scenarios can be quickly tested and their implications evaluated. The final solution should, however, be tested with the detailed model to ensure that the proposed solution has no adverse effects on the system hydraulics under more extreme rainfall criteria. The UPM Manual listing of SIMPOL was based on a maximum storm duration of 12 hours. On the east coast of Scotland, it is quite common to have storms of longer duration than 12 hours (and this is reproduced in STORMPAC). Again, it is possible to adjust the parsing of the rainfall data line to accommodate storms of longer duration.

It should also be possible, with some further manipulation of the spreadsheet files, to carry out a continuous simulation so that the effects of storm sequencing can be considered. This would give the simplified analysis a major advantage over methods requiring the use of detailed models, particularly in the consideration of storm tank filling and emptying sequences.

A further advantage in considering the use of simplified sewerage system models is in the consideration of the system hydraulics by the user. The process of constructing the spreadsheet model causes the user to break away from the routine of detailed model results and makes them think about the operation of the system from a different viewpoint. In a number of cases, a failure to obtain a reasonable calibration between the detailed and simplified model has led to an examination of the detailed model. In one instance, a poor calibration was due to the incorrect representation of an overflow structure in the detailed model rather than a problem in the simplified model.

Future development

To date, simplified sewerage system models have been used by the Authority primarily for hydraulic evaluation. The Perth system represents an opportunity to test and possibly develop the pollutant aspects of SIMPOL. A significant amount of quality data has been gathered by the Authority in joint research studies with UoAD. These data are currently being used to construct a quality model of the sewerage system. It should be possible to test the SIMPOL pollutant prediction capabilities by directly calibrating against the raw pollutant data sets, as well as calibrating against the detailed quality model.

Conclusions

The STORMPAC software has been demonstrated to produce reliable representations of the local rainfall conditions for particular areas. A minimum data requirement of local monthly statistics should be used to regionalise the software. SIMPOL representations of sewerage systems allow for rapid evaluation of various upgrading options. Given sufficient care in the construction and calibration of the simplified models, no loss of accuracy with respect to predictions has been encountered. The simplified modelling approach has significant advantages over more traditional techniques in terms of the ability to consider the full range of significant rainfall events. Further development to be able to consider sequencing of events will benefit operational and design criteria for, in particular large storage tanks.

The views expressed here are those of the authors and not necessarily those of the North of Scotland Water Authority or WRc.

Applications of STORMPAC and SIMPOL

David Wotherspoon North of Scotland Water Authority

Question Richard Kellagher IHS

You mentioned using daily rainfall totals in the analysis, did you look at the disaggregation within the event

Answer

We decided to test the programme as far as we could to satisfy ourselves that it functioned well. We were not able to test the disaggregation process within this, but this has been tested by the makers of the programme and they have published information on the validity of the disaggregation process.

Question Ian Noble Montgomery Watson

You said 1 and 4 hours inter storm dry periods were used did this have an effect.

Answer

The one hour period was used to define what constitutes a storm event. This could have been set to whatever you wish to define the start and end of storm events. This is an important consideration in, for example , the filling and emptying of systems if sequencing of events is to be considered.

Question Simon Spooner Mott MacDonald

Did all the overflows have free spills or were some surcharged under storm conditions ?

Answer

Some were and some were not. We looked at a range of events and how HydroWorks was reporting the spill rate. Inevitably what ends up in the conversion from HydroWorks to SIMPOL is a compromise and you need to be careful during calibration.

If you have a good HydroWorks model to start with you can do a good calibration.

Question Martin Shaw McDowells Consulting Engineers

Have you done any long term monitoring? have you monitored over a full season.?

Answer

No the main calibration of the SIMPOL model was based on the HydroWorks model which was already verified.

Monitoring will take place if and when we move into the solution stage.

Comment Jon Farrer Bullen Barber Ltd

A lot of time and effort is spent on monitoring for model calibration. There is no equivalent push to on long term monitoring. Is there now a move to more post project appraisal.

Comment David Balmforth Sheffield Hallam University

We are doing some post project appraisal for one Water Company so we should get some feedback, but a lot more could be done.

Comment Sean Adam Greenworld Instruments

Technology could well help, with the cost of on line monitoring reducing it will be easier to do post project appraisal.

I believe that the basic sampling currently being done will only last for another 15 years, it will then be all on line. The cost then will be in the maintenance of the systems.