Hydro International plc
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Solutions to Intermittent Discharges from Sewerage Systems and Wastewater Treatment Works

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CSO Design Auditing Procedure

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ABSTRACT

This paper outlines a fast-track audit procedure for **C**ombined **S**ewer **O**verflow compliance to **UPM2**[1] or similar. It is based on the standards of **FR 0488**[(2)], recently modified by a Wapug proposal (Autumn meeting 2000, not yet finalised), research by the **University of Sheffield** and **Sheffield Hallam University** and the more recent data published in **UPM2**[1] and a series of **CSO Research Group** projects published by **UKWIR**[4,5,6,8]. We are grateful to Professor Adrian Saul for his assistance in testing the Win*Dap* software.

Introduction

CSO design is perceived as a complex procedure that takes several weeks (or months) to execute. It is also assumed that checking submissions to the required standards will be very time consuming. This may result in managers and supervising engineers adopting strategies to avoid auditing aspects of the designs. However auditing key features is a relatively simple affair. These features are quality indicators that are vital if informed judgements are to be made by clients, approving authorities and supervising engineers.

The audit assumes that time is of the essence (or a national shortage of manpower) and we have devised a procedure to cover the following aspects of the design:

- Survey
- Rainfall
- Capacity Standards
- Aesthetic Standards : Screen & CSO Dimensioning.
- Spill Frequency Standards: Bathing Water
- Storage/ 99 percentile/ Quality & Fundamental Standards

All these elements may be examined in 4 stages using Micro Drainage's Win*Dap* software.

(If you wish to skip the overview and go straight to the audit please turn to page 7)

Before we proceed with the audit we will give an overview of the problem and the available solutions. Water Quality is a complex subject but there are only a few options available to the engineer at the point of discharge. If we examine the problem in the context of the UPM2 requirements we will be able to define a quick and effective auditing procedure.

The paper is therefore presented in 4 parts:

1. **What are aesthetics and water quality in relation to intermittent discharges?**

2. **Available Solutions**

3. **UPM2 Rainfall requirements**

4. **Audit Procedure**

Part 1: Aesthetics and Water Quality

Water pollution may be approached from two perspectives:

- Those near the water – walking, boating etc.
- Those in the water – swimmers, wind surfers, fish etc.

There are two comparable technical categories for these two perspectives:

- **Aesthetics**
- **Water Quality**

The **aesthetics** criteria are what they imply; if you can see the pollution then it is visually unacceptable. What we can see is aptly termed "gross solids". Some of these gross solids e.g. toilet paper, crisp packets etc. may not cause the fish any major problem but they would be unacceptable to a member of the public walking his dog along a river bank.

Water quality may not always be a visual issue. You may see dead fish in an extreme case but you may not be able to see the dissolved matter that caused their deaths. In fact, poor water quality may not be visually displeasing to the dog walker but it is very upsetting from the fish's perspective.

Part 2: Solutions for Aesthetics

This is achieved by the removal of gross solids i.e. solids larger than 6 mm in two dimensions.

Two solutions for aesthetics have been used during the recent AMP2 period, **screening** and **aestheticiser**[3].

The aestheticiser approach is to allow time and tranquil conditions to settle gross solids so they don't pass over the weir. This is achieved by enlarging the CSO and its upstream pipe, which increases storage.

Recent research[(8)] (Walton *et al*, 1997) however demonstrated that most gross solids have a settling velocity which is close to zero and they neither settle nor float. These characteristics were obtained at the Hoscar site and they may vary from catchment to catchment. Nevertheless additional storage at a CSO will reduce the quantity of pollution spilt and improve both the aesthetics and the water quality of the receiving water. What cannot be guaranteed is that large gross solids will not pass the weir and the only reliable method to ensure this appears to be the use of screens.

If you provide a **6mm screen** then you will stop a percentage of the gross solids from entering the spill. A slightly bent cotton bud may be larger than 6mm in 2 dimensions but it can be passed through a 6 mm hole in a screen therefore **a screen cannot be 100% efficient** at preventing gross solids from passing. Many screens used to meet the 6 mm standard have 4mm spacing between the bars or employ 4 mm holes to improve performance.

There are other problems e.g. toilet paper may disintegrate and pass through a screen before forming larger particles downstream of the screen. Also the screen cleaning mechanism may macerate some gross solids forcing them through the screen.

Therefore as screens are not 100% efficient and different mechanisms perform differently it is necessary to **test each screen** and assign an efficiency value to it.

The performance of a screen also depends on the rate of flow approaching the screen. Therefore it is also necessary to **vary the screen efficiency with loading**[(4)].

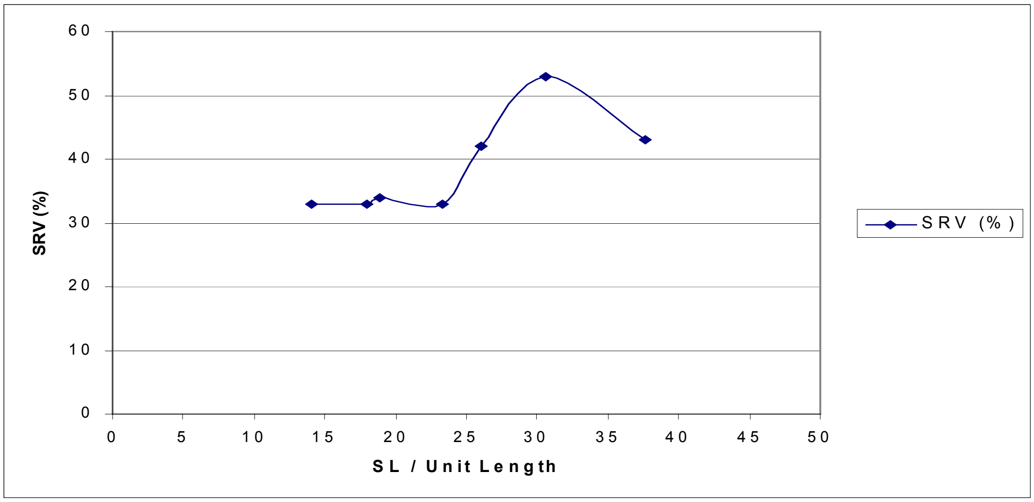

Fig 1. Example of the variation of screen efficiency with screen loading (l/s/m) – ref.4.

The variable screen efficiency is used to calculate the performance of the installation minute by minute through the storms. This performance is then compared with a standard*. The criteria for that standard are published in **appendix C of UPM2[(1)].** New and novel devices may now be tested and their performance measured against the UPM2 criteria. (*The site-specific standard will be set by the appropriate environmental regulatory body; e.g. the Environment Agency, Sepa and DoE NI. "The EA expects the use of the planning procedures outlined in the second edition of the UPM manual in developing all sewerage schemes" [(11)])

It is important that the performance criteria are based on the same testing regime as the commercial screen tests. The 10 mm and 6 mm criteria were obtained from the same testing site at the **National CSO Test Facility** at Hoscar as was used to determine the performance of commercially available screens. We obtain average values of SRV (screenings retention value) for **6 mm and 10 mm screens of 34% and 28%** respectively from the data in UPM2, figures C1 to C3. According to previous studies[(2)] 6mm screens produce efficiencies as high as 60% but none of the data in UPM2 demonstrate such high efficiencies. As the commercial screens were subjected to the same test it is reasonable that they should be compared to the 34% SRV standard. Some commercial screens did produce 60% efficiencies some of the time but only one had an average efficiency as high as 60%.

Also the screens do not have to perform to the 6mm standard all the time **(Standards for protecting amenity use** UPM2 Table 2.6). From the 6 mm setting to the 10 mm setting* the screens must deliver 28% efficiency, comparable to a 10mm screen.
(*6 mm setting treats 80% of the volume in a typical year or 50% of the volume of the 1 year RP design event. 10 mm setting is based on 5 year RP design event[(3)]. Return periods may be calculated in the Win*Dap* software to **FSR or FEH[9]**)

The headloss produced by the screens and the backing effects upstream may also be analysed[12].

While the calculations are intensive Win*Dap* plots the UPM2 criteria against the screen performance and the engineer can see the results at a glance.

Solutions for Water Quality

The quality of the receiving water may be improved by treating the sewerage or by reducing the quantity of raw sewerage spilt. Treatment at the CSO is seldom practicable or economical. Therefore the solution is to retain as much of the sewage in the sewer as possible so that it may be treated downstream.

The **primary means of solving water quality at a CSO is storage** and the problem is how much and where?

The **Computer Aided Simulation Design Framework** (CASDeF) provides the quantity of storage needed. This control program runs up to 10,000 simulations automatically to determine the storage requirement for a given set of conditions that are specified by the engineer. This may be used to extend the audit to examine alternative options.

To refine the design and place the storage at the best location from a water quality perspective the variation of pollution concentration over time is required. This is based on the **Saul/Gupta** method which is the subject of other papers and discussed in detail elsewhere(7). Different water quality methods can yield different results and the more complex the method the more likely it will be set-up incorrectly. To ensure that the results are within reasonable limits we have also implemented the **UPM2 EMS** method. While both methods may be calibrated this is not a requirement of all the CSO designs. The default values may be used to compare the **quality performance** of different CSO configurations.

Combining the two perspectives

Water quality and aesthetics are not entirely separate issues. Both demand that the CSO be designed to **"Good engineering practice".** If the weir is too short, too low, or the flow is too turbulent then the CSO will not perform well. The UPM2 manual defines "good engineering practice" as a design based on FR 0488(2). The only variation to this, proposed by a leading researcher, is that the weir length need only be as long as that needed to install a suitable screen. Wapug have published revised chamber sizes for screens on their web site(14) (any variation, would have to be approved by the environmental regulatory body). Further detailed experiments on **scumboards** could also be taken into account(6). These criteria are built into the software.

Storage provided for improvements to water quality will also retain additional gross solids and hence improve aesthetics. The aesthetic criteria (UPM2 Table 2.6 etc.) also demand a limit on the number of spills allowed if 6mm screens are not used. This limit is usually achieved by providing storage which in turn improves water quality.

The best of both worlds is to combine a water quality model with the aesthetic design requirements to provide a comprehensive analysis and design procedure which has been incorporated into Win*Dap*.

Part 3: UPM2 Rainfall Requirements

The type of rainfall data will depend on the standard required under UPM2. The following is a summary of the rainfall data needed for the various tasks.

- Typical Year – Amenity standard.
- Bathing Season – Bathing Spill Frequency standard.

- Annual Spill Events – Water quality fundamental standards.
- Summer Spill Events – Water quality fundamental standards.

- Return period 1,5 & 20 - CSO design and screen compliance to UPM2.

Guidance on the rainfall data needed to design a CSO is given in sections 4.2 and 6.2 of UPM2.

Ideally we need 10 years or more of continuous hourly historical data for the site. Return period analysis and comparison with threshold depth values for 20 years + of daily data can determine whether this data is acceptable and whether it is missing critical events. If synthetic data is used then it should be demonstrated that it has been compared with at least 20 years of daily records, again using threshold analysis.

This raw data may then be developed into a **"Typical Year"** events set and if necessary a "Bathing Season" events set.

The **"Typical Year"** set is used to determine compliance with the Amenity Standard (UPM2 2.5/6.4.) or making a rapid assessment of quality performance *"when the effort involved in using the 10 year files is prohibitive"* (UPM2 6.2.1.a) . It could be argued therefore that an independent audit could limit itself to Typical Year data and only extend the investigation if problems were found. This is the approach we have adopted to produce a quick audit.

The "Bathing Season" rainfall may be used to determine compliance with the bathing water spill frequency standard (UPM2 2.4.3).

The ***Rainfall Workshop*** automatically defines events in relation to the network's drain down time (UPM2 4.2.5). *If the events are not properly defined for the site characteristics the entire design could be erroneous.* It is not true that rainfall files used on one job will be suitable for another in the same locality.

The **Rainfall Workshop** allows detailed return periods to be calculated for all the rainfall data and this together with **threshold analysis** (UPM2 4.2.4), including each year's standard deviation to mean thresholds, assists in determining if the correct "Typical Year" has been chosen.

For **water quality** a **“Summer Season Events**” set may limit the data to the summer months if breaches to the **“Fundamental Intermittent Standards”** are clustered in the months May to September (UPM2 section 2.3). These clusters are likely as temperatures are high and flows are low in summer (UPM2 section 6.2.1a).

As the project will usually require either summer or bathing season events and they are effectively the same in UPM2 (May to September) a summary of the subsets required of the Annual Rainfall Series is as follows:

Annual Rainfall Series (minimum 10 years) :-	Typical Year Events. Summer/ Bathing Season events.

These files may be further subdivided to save time for design purposes and this is discussed elsewhere[13].

In addition to long time series, 3 return period sets are required. Again the **Rainfall Workshop** enables these series to be calculated using FSR or FEH methods.

The 1 and 5 year return period sets are used as part of the analysis for compliance with UPM2 screen performance. The 20 year storms are needed “………. to check the safe behaviour of the chamber under extreme flow conditions (e.g. 1 in 20 year return period) to ensure that no uncontrolled flooding or structural damage occurs as a result of the chamber configuration.” [2].

Several of the above files are generated automatically in the CSO wizard and it is not necessary to generate them all for the purposes of an audit.

Part 4 Audit Procedure

The entire audit is completed in 4 phases using the following **Win*Dap*** modules.

I	**Quam:**	Network survey
II	**Rainfall Workshop:**	Rainfall Audit
III	**CSO Wizard**	Capacity Standard. Spill Frequency 99 Percentile Standards Aesthetic Standards: Screen performance & CSO Dimensioning
IV	**20 Year Critical Summary**	Hydraulic Performance

I Quam: Network Survey

If the survey is flawed then every part of the design process will be flawed.

The auditing software for network build is based on the examination of real data. We have so far identified 66 categories of errors and these are being extended. The program reports these errors and classifies them.

If the errors are numerous and of a serious nature the whole network may need to be resurveyed. However in most cases specific areas will need to be checked and corrected. Many networks display a significant number of errors and few systems will pass the network build audit without some correction and clarification.

The process takes five minutes to execute.

II Rainfall Workshop: Rainfall Quick Audit

It should be possible to verify the following in less than 30 minutes:

- Inspect the rainfall files and confirm the list complies with the UPM2 requirement.
- Conduct a return period analysis to ensure the data set is long enough.
- Check drain down time by comparing the number of events generated.
- Confirm the choice of typical year using threshold analysis.
- If FSR rainfall is used then compare it with FEH.

If the network survey and the rainfall data are of an acceptable standard then an audit of the design may proceed. If however they are not of an acceptable standard the audit should be ended and the design should be re-engineered with the correct data.

III CSO Wizard: The heart of the audit

Most of the audit is conducted in phase 3 “The CSO wizard”. This single computer run may be utilised to check the majority of the design standards.

The CSO Wizard includes all the Typical Year storms plus the 1 and 5 year return periods. It automatically calculates the dimensions for the CSO and screens, the maximum settings of the CSO and screens, the “typical year” spill frequency, water quality, percentile spill etc.

Capacity Standards (CSO Wizard)

“A particular environmental regulator’s policy may also have a requirement for a minimum level of wastewater system capacity or performance”(UPM2 2.1.4).

Examples of these standards are Formula A and the Scottish Development Department standards. Even if these standards have not been specified they are very useful in checking whether aspects of the design are within widely practised limits.

Formula A – The CSO Setting
While **Formula A** may not be a requirement of the regulator in every case it is nevertheless regarded as a "rational method of arriving at a setting"[2]. If the continuation flow is much less than 50% of Formula A then the downstream network will probably have to be upgraded before storage is considered. This is because it is likely to fail the "Performance criteria for CSOs" (UPM2 2.2).

The value of Formula A at every node in the system is calculated by the software.
The Maximum outflow from the CSO is shown on the critical summary of the CSO Wizard.

Spill Frequency Standard (if applicable).

In addition an "emission standard" such as the bathing waters spill frequency standard may be specified. The bathing season rainfall files (see Part 3) must be run. If the CSO activates less than an average of 3 times per bathing season then it passes.

Win*Dap*'s Critical Summary Wizard reduces this check again to a one run procedure.

However for the purposes of the quick audit we may use the "Typical Year" storms run in the **CSO wizard**. Although the 3 spills may be exceeded in any one summer season they should not be exceeded greatly between May and September of the "Typical Year" otherwise it is likely to fail the "all years summer average".

Aesthetic Standard

The aesthetic criteria are defined by table 2.6. UPM2. If the spill frequency is greater than 1 per year then we must provide a combination of **6 mm and 10 mm screens** or equivalent performance to comply with High Amenity.

The Typical Year events are used to determine the number of spills and these have been run in the CSO wizard. However, if it is accepted that the CSO activates and 6mm screens or equivalent are to be used then there is no practical difference between the High Amenity and Moderate Amenity specifications.

We do need to check the following for compliance with aesthetic criteria:

- **CSO dimensioned to "Good Engineering Design".**
- **Screen sizing & performance to UPM2 appendix C.**

The water quality output gives details of overflow volumes, flow splits, screen efficiencies and settings, CSO recommended dimensions, weir length, height etc, and Water Quality to Saul Gupta and UPM2 EMS.

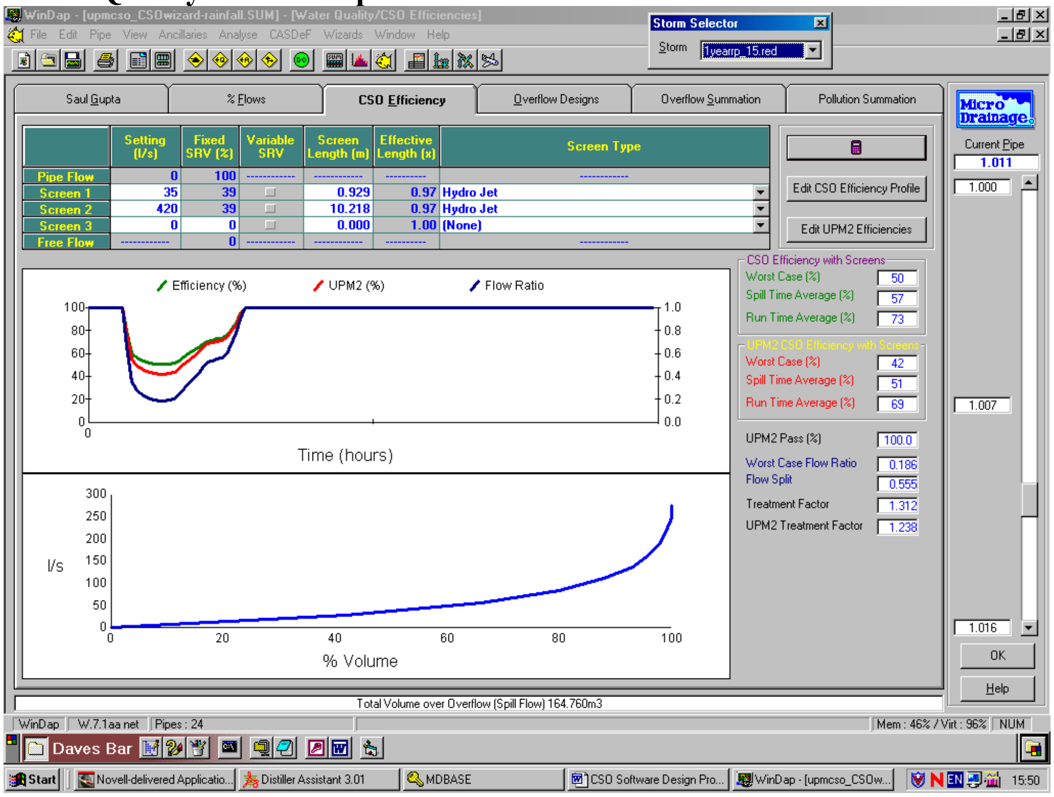

Fig 2: Screen efficiencies.

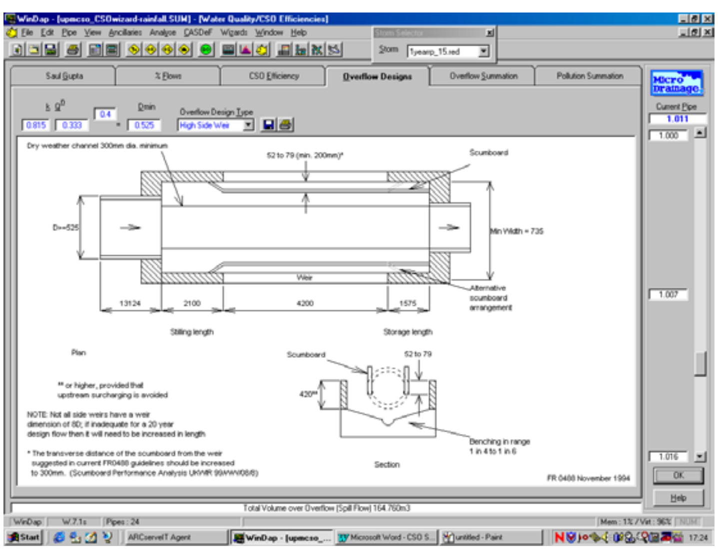

Fig 3 CSO Dimensioning [2,14]

99 Percentile Standard

The water quality output from the CSO wizard also shows the percentage of time in the Typical Year that the CSO has overflowed. In the example presented with this paper it is 0.7%. It will therefore not affect the 99 percentile standard of the receiving water (UPM2 2.3.3). This is not a big surprise as the system was designed to accommodate Formula A.

IV 20 year Critical Summary

The design must be verified by some final hydraulic checks. The additional headlosses due to the installation of the screen are also taken into account.
The 20 year Summary Wizard is run to check the "safe behaviour of the chamber" in accordance with FR0488.

This completes the quick audit

Storage Quality & Fundamental Standards

The UPM2 manual (Section 2.3) is a compliance standard with respect to water quality. You have to first produce several "good engineering design" options and test the river quality produced under the fundamental standards so the above checks would have to be completed for CSO dimensioning etc. A full Water Quality study is the most time consuming and costly element in the analysis of intermittent discharges and it is not usually required. It is therefore not included in this paper as a quick audit.

There are a number of checks that may be carried out quickly and the audit may be extended particularly if the CSO has not performed well in respect of the above criteria. Again a Typical Year may be used and an example of the type of output is shown in figure 4. Details of how to obtain these results are given in the CSO Software Design Procedure to UPM 2nd Edition [13].

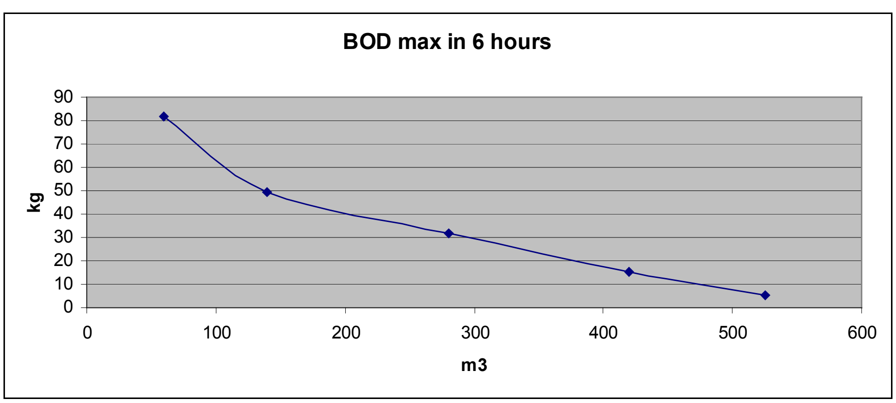

Fig 4. Improvement in BOD discharge v storage volume

Conclusions

There are many aspects that could be included in an audit and we could extend it further. A reasonable approach is to check key features and only extend the audit if problems are identified. The paper demonstrates that an audit can be designed to validate CSO design, which is not very time consuming. While it will depend on the standard required and the size of the catchment, nevertheless it is evident that most CSOs could be audited in hours and not days.

Although the paper has been addressed to managers and supervising engineers I hope it also provides a useful checklist for designers.

A more detailed approach to the design of CSOs is available in reference 13. Alternative designs for CSOs and useful advice on access and ventilation is given in reference 14 which is only in draft at the time of writing.

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