Field Performance of Combined Sewer Overflows

C. Jefferies, Wastewater Technology Centre
Dundee Institute of Technology, Bell Street, Dundee DD1 1HG

1 Strategic Considerations

Many current sewer rehabilitation schemes require a rationalisation of combined sewer overflows (CSOs). The trend is for an ever smaller number of larger installations which replace inefficient, badly designed or ad-hoc overflows. Storage is also very often incorporated in the new installations, this being either off-line in addition to the overflow device, or on-line, in which the overflow and storage are within the same structure.

Historically, designs for overflow structures have been based upon the results from steady-state model testing with efficiencies derived from studying the behaviour of synthetic material inserted into the flow stream. With the increasing incorporation of storage at CSO sites, and its influence on the unsteady flows encountered in sewer systems, steady state testing has become of lesser importance. At the same time a greater understanding of the behaviour of sewer systems and the requirement for the consenting of CSO discharges have led to a natural interest in their performance and monitoring.

Monitoring of CSO performance may be required for a number of reasons:-

- Provision of data supporting the selection of CSO types.
- Verification of flow and quality models -WALLRUS & MOSQITO.
- Approval of discharge consents.
- Guidance on the likely discharge rate (or volume) and pollutant concentration (or load).
- Stream impact studies for both water quality and aesthetics.

2 Influences on Performance

Each field CSO installation is unique within its region, catchment and site specific details. The number of variables affecting performance are legion and consequently any monitoring programme must be seen as a one-off study from which general conclusions may be drawn provided sufficient such studies have been carried out at comparable locations.

The fundamental influences on performance may be presented as questions which must be answered at each site and for each event. They include:-

- The overflow setting and its relationship to the inflows.
- The volume of storage which must be filled prior to spillage.
- The conditions antecedent to the event.
- The mean quality of the discharge.
- Whether any improvement in quality occurs between inlet and spill.

The last item is of course of major interest to the CSO specifier or designer who has to select between the various types of structure available. These questions can only be answered for a specific location after an extended monitoring programme has been completed. Typically, where quality monitoring is involved, this would require at least a dozen events to be monitored and, should significant storage be incorporated, then the study period might be at least a year.

3 Measurements for Performance

The measurements required increase with the complexity of the study being undertaken. In order of increasing resources required, these are:-

- Flow monitoring.
- Small bore sampling.
- Stream sampling (with measurements of inputs).
- Gross solids sampling.

3.1 Flowrate

It is virtually impossible to assess the performance of a CSO without flow monitoring. A minimum of two flow monitors must be deployed for at least part of the study and preferably all flow streams should be monitored. To avoid excessive use of equipment it is common practice to include a calibration period in which, for example, spill characteristics are related to the readings from one monitor. This would normally be at the inflow to the CSO. If such a calibration period has been successful then monitoring of levels only, from which flows might be computed, may be sufficient. However there is little saving in using level-only monitors, and the information gained is much inferior to that from level and velocity measuring devices.

Two particular difficulties arise with the monitoring of CSOs. The duration of monitoring may be excessively long, and, with monitors installed within structures, calibration of velocity and depth readings may be difficult.

3.2 Small bore sampling

The conventional samplers used are portable and have twenty four sample bottles. During storm events their operation is triggered by a rise in water level, most frequently measured at the inlet although, when spill measurements only are required, this may be used. Ideally continuous samples should be taken during the period leading up to an event however the cost is frequently prohibitive. To monitor effectively the first foul flush, variable time intervals have been recommended, typically 3min followed by 7, 15 and 30 minutes to ensure that the maximum rate of concentration variation is detected. An alternative strategy is to use a continuous 10min interval between samples.

Gathering the samples is of course only a part of the effort involved in quality monitoring. No in-situ quality monitors are available to operate in the environment of CSO operation and the samples must be lab tested for the required determinands. The number of samples may be large with a prolonged event requiring one hundred or more to be tested so the task is only possible in very well appointed organistaions.

3.3 Stream quality sampling

It may be argued that the performance of a CSO spilling to a watercourse may only be assessed by measurement of the effects on the watercourse. It is well established that monitoring of water qualities in the stream is a poor indicator of the impact due to the rapid variations of the flow and concentration. A better approach is to carry out longer term monitoring involving visual inspections and macroinvertebrate counts in addition to measurement of the standard physico-chemical determinands. This type of information is relatively easy and cheap to obtain, however it may be of little value without monitoring of both stream and sewer spill flows, consequently the resources required may be large.

3.4 Gross solids sampling

Perhaps most concern relating to CSO performance centres on the behaviour of gross solids. The majority of complaints of CSO discharge relate to the amount of visible solids released and questions are frequently asked as to the comparative performance of screens and overflow structures in this respect. Equipment for gross solids monitoring is both expensive and time consuming to operate. WRc have developed a gross solids sampler, which physically intercepts solids, and a monitor which uses an infra red beam to create a detectable image. These devices require three phase power and telemetry links for operation and realistically can only measure the behaviour at the CSO itself. To install such an item of equipment where the storage was significant would mean that operation would be extremely rare, and the costs per operating cycle would be very high.

Simpler devices are available for installation on spill weirs, but their use has yet to become widespread. The Trash Trap was developed by the author to monitor spill flows, and the Franklon screen, which was developed to remove trash, may also have a place in performance assessment.

4 Assessment of Performance

4.1 Efficiency Definitions

The term now in common use for expressing the field performace of a CSO, including storage is the **Treatment Factor**. This is in turn expressed in terms of **Total Efficiency** and **Flow Split** where:-

$$\textbf{Treatment Factor} = \frac{\textbf{Total Efficiency}}{\textbf{Flow Split}}$$

The **Total Efficiency** is the total storm load retained as a ratio of the inflow load during the storm and the **Flow Split** is the total volume of flow in the storm expressed as a ratio of the inflow volume. The **Treatment factor** (TF) can be expressed for any pollutant determinand which has been measured and requires the sampling programmes outlined above. TF expresses the comparison of load and volume separation at the CSO and may be used to include the storage or simply relate to conditions at the flow split. A value greater than unity implies that an improvement in quality above mere flow split occurs, whilst for less than unity the converse is true.

4.2 CSO Performance - Without Storage

The principal function of the CSO structure is to ensure that there is effective hydraulic control and flows are split correctly. It is generally considered a bonus that quality improvement also occurs. Studies at Dundee and Sheffield have produced TF values averaging unity over a range of events confirming that no quality change occurs. Indeed, with high side weir and stilling pond overflows, values of TF are frequently less than unity showing that under certain circumstances these devices preferentially spill solids.

Some evidence is available to show that the Storm King unit does improve quality, at least in terms of suspended solids, and for this type of device, few TF values less than unity have been recorded from Aston or Dundee. The studies of CSO performance show that the hydraulic behaviour, whether spill occurs or not, is far more important in preventing pollutant discharge than any improvement of quality across a CSO.

These comments refer to the behaviour of pollutants which can be sampled using small bore samplers. No data are yet available to show whether gross solids can be separated, although evidence gathered by the author and in studies by WRc in Swansea suggests that, in common with the suspended solids behaviour, no change of gross solids quality will occur across a CSO without storage.

4.3 CSO Performance - With Storage

The principal function of storage is to retain pollutants within sewer systems. Consequently the **Total Efficiency** of an installation with large storage will be high, reflecting the probability that the volume will have been sized to retain all but the most prolonged events. It is almost by default that the storage volume also acts as a very efficient settling tank which removes all floating and relatively easily settled solids. This characteristic has been shown in several studies in which the principal material remaining in the flow at discharge have been neutrally buoyant plastic strips. Such material can only be removed by screening which is essential if the consent condition is that zero visible solids are to be discharged. The provision of storage may however allow simple, non-automatic screens to be installed to ensure visible solids are prevented from being discharged. Such screens would include the Franklon screen for small discharges, or the trash trap for larger installations.

5 Conclusion

Monitoring programmes for CSO operation are long term and expensive undertakings. The results of studies to date show that the volumetric performance of the CSO is of considerably greater relevance than the pollutant separation behaviour. Where the principal concern of discharge is the aesthetic impact, then a device of low volume, with some quality improvement such as a Storm King separator followed by a simple screen may produce a very cost effective solution.

FIELD PERFORMANCE OF COMBINED SEWER OVERFLOWS, C. JEFFERIES, DUNDEE INSTITUTE OF TECHNOLOGY

Question

Tim Webster, Seven Trent Water

The long term flow monitoring was expensive, did you work to a lower specification of flow survey with less frequent site visits, and did you have reasonably reliable flow survey performance?

Answer

In CSO monitoring you tend to visit when spill occurs, the principal reason being you must pick up the samples quickly so you can measure the polutants properly. On these visits the monitor calibration work can be carried out. You are mainly interested in depth information, which is easy to measure. The level is also the parameter which goes out of tune quickest on a standard flow monitors.

Weekly visits can be reduced to 3 weekly inspections in dry weather.

Performance and reliability could be discussed at length but if power can be provided, rather than using batteries, then reliability is increased by a factor of 3 to 4.

If you get 4 or 5 months out of a logger before bringing in for repair you are doing very well.

It is surprising what can cause failure, 3 loggers went out simultaneously after lightning strike even though they were underground.

Question

Andy Sharp, Binnie and Partners

Do you have any comments on treatment factor for low, high side weir overflows?

Answer

Unity!! It depends what you look at, I looked at small bore samples COD BOD, only the flow volume split counts. High side weirs, stilling ponds, have no storage and act as flow split devices. They do retain heavier faecal matter within the DWF channel but do not retain neutrally buoyant material. Suspended solids unity! visible solids, unity! faecal matter possibly 1.25.

Question

Jim Allen, Severn Trent Water

If the paper you seem to consider the aesthetic value of overflows more important than other impacts on the receiving water course such as BOD COD etc. did you consider these?

Answer

Yes. What was implicit in the paper was that it was looking at modern "designed" overflows not looking at "hole in the wall" type.

The storage at an overflow retains flow and has a very significant effect on overflow spill. This cannot be given a treatment factor ie. if an overflow has a treatment factor of unity but the storage is sufficient to retain all flow in the system. The treatment factor is meaningless as a measure of performance.

There are still a small number of occasions when these overflows do spill, the storage means that most of first foul flush is stored and that the river or brook has had time to build up its flow so the pollutant effects are small. At this stage the aesthetic aspects are the most important.

Question

David Balmforth, Sheffield Hallam University

A quick comment on performance trials on a range of overflows that I am involved in:

1. *Do get improvements in BOD in the finely suspended material in newly designed overflows with storage. No improvement in old designs though some small improvement with extended stilling pond type and vortex type.*

2. *Treatment factors vary more between storms at a single overflow than between overflow types. Maybe we should look for a better measure of performance than treatment factor.*

3. *What ever form of trash screen is used it will pass some visible solids. Zero visible polutants is not possible. Any standard that asks for this will not achieve it.*

Answer

I agree with virtually all the points.

Question

Dave Walters, MW Barber

Did you find any correlation between parameters COD, BOD Ammonia?

Answer

Unfortunately in my research I became unstuck in this. Early in the study a correlation between COD and suspended solids was observed.

Later in the study the correlation was found to be a bad assumption. Other people have linked COD and suspended solids. Certainly no correlation with ammonia. You are on shaky ground trying to look at one as a way of measuring another.

If you want to know about BOD measure it don't rely on second hand relationships.