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Investigation of the Performance of Combined Sewer Overflow Screens

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To Patrick, for always being there

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ABSTRACT

A major objective of the NRA guidance note for controlling combined sewer overflow discharges (NRA, December 1993) is to minimise the presence of objectionable solids and persistent material in watercourses. The guidance note states 'this can be achieved by a number of means, for example the design of the overflow structure or the provision of screens' (NRA, December 1993). In his review of the performance of storm sewage overflow structures with respect to aesthetic criteria, O'Sullivan (1990) found that there was a shortage of information about the quantities of gross solids discharged from combined sewer overflows (CSOs) and there was no consistent approach to the use of screens on CSOs. He recommended that further research work should be done to evaluate the effectiveness and viability of screens at CSOs.

A field and laboratory study was carried out to investigate the performance and efficiency of different types of CSO screens, identify the sources and type of gross polluting solids and identify the factors which influence screen performance. Two stilling pond CSO bar screens and two sewage treatment works (STW) inlet bar screens were evaluated by collecting the gross solids retained by each screen together with any gross solids passing through the screen. Flow data were obtained using flow survey equipment. A series of tests were also carried out on five 6 mm screen meshes at two STW sites and in the laboratory. Additional tests were performed on the five screen meshes in the laboratory to determine head losses.

Results have shown that screen retention efficiency is dependent on the aperture size of the screen face. The larger the aperture of the screen face the lower the retention efficiency. Mechanically raked bar screens with 6 mm spacings were found to have a maximum overall retention efficiency of 30%. For 6 mm mesh screens this figure was 60%. The main polluting gross solids were found to be of dry weather flow origin. Fine paper, leaves, sanitary towels and tampons formed the bulk of the gross solids samples with condoms and cotton bud sticks forming less than 0.1% of the overall sample mass. There appears to be different transport mechanisms for different types of gross solids where some are continually transported in the sewerage system, whilst others require a threshold velocity of flow before being transported. The bulk of the gross solids arriving at a CSO chamber during a storm event was found to arise from the dry weather flow prior to the storm event. The total mass of gross solids presented to a CSO screen was shown to be dependent on the mean overflow intensity of the storm event and this relationship was used to develop a predictive model, based on the upstream population and average usage figures of sanitary products and toilet tissue. The research has also shown that prediction of the screen retention efficiencies obtained in the field is possible with full scale laboratory tests providing care is taken in the laboratory when simulating gross solids.

CHAPTER 1 INTRODUCTION

1.1 Sewerage Systems

In developing sewerage systems for urban areas engineers are faced with two different major problems. One is to effect the removal of domestic and industrial wastewaters and the other is to allow surface water run-off to enter watercourses without causing undue flooding, erosion or pollution. Three types of sewerage system exist within the UK:

The Combined System

The Separate System

The Partially Separate System

All three types of sewerage system result, to a greater or lesser extent, in the discharge of pollution to our watercourses.

The combined system is one in which a single system of pipes conveys foul sewage and surface water to treatment. This is acceptable providing the system has the capacity to transport the dry weather flow of foul sewage together with the surface water from any storm to treatment and the sewage treatment works has sufficient hydraulic capacity to receive, store and treat all storm flows. Few combined systems exist which are capable of doing this. Most frequently make use of storm overflows to restrict the amount of sewage conveyed for treatment and disposal. The storm sewage and hence a proportion of foul sewage, in excess of a predetermined rate of flow is discharged into the nearest watercourse. The discharge from a combined sewer overflow (CSO) should only begin when the flow passing forward down the sewer reaches a predetermined rate and the maximum quantity of polluting matter in the sewage should be carried forward down the sewer.

The separate system was devised to obviate the discharge of untreated foul sewage by providing completely separate foul or sanitary sewers, for transporting domestic and industrial wastewaters, and storm sewers, for carrying surface water runoff and storm water. The surface water system usually discharges into the nearest watercourse untreated. The wastewater is conveyed to a sewage treatment works for processing before entering the watercourse. The separate system eliminates the need for storm overflows along the system and storm tanks at sewage treatment works and does not deprive rivers of run-off from their catchments. However, the cost of two sewer systems is high and problems may arise from wrong or illegal connections where foul sewers are connected into the surface water system and contaminated water is discharged untreated into the watercourse. The connection of surface water sewers into the foul sewer can potentially cause greater problems by overloading the foul sewerage system resulting in upstream flooding and either, a reduced efficiency in the treatment process downstream, or, severe flooding of the treatment works. The discharge from the surface water system may be contaminated with oil, road grit and chemicals washed from highways and other paved areas causing pollution of the watercourse. The use of dual manholes in separate systems may also cause pollution of the watercourse when surcharging due to storm conditions or blockage occurs and the two systems effectively become interconnected.

The partially separate system has separate surface water and foul sewerage systems but a proportion of the surface water which comes from parts of roofs, yards and any other connected areas drains into the foul sewers. This system originates from the expansion of industrial towns at the turn of the century, when demands for housing grew as the number of factories and factory workers grew. Row upon row of terraced houses were built with back yards and outside lavatories, the runoff from the fronts of the dwellings e.g. roofs, paths, drives etc. drained into the surface water system along with the runoff from highways and pavements. The backs of dwellings e.g. roofs, yards etc. were drained into the foul system together with the wastewater from the lavatories, these connections being the most convenient and cost effective at that time. Again as with the separate system, problems arise through wrong connections.

1.2 History of the Sewerage System and evolution of CSO Regulations in the UK

As towns grew and areas were built upon, natural watercourses were culverted and surface water channels and gullies were connected into them to carry surface water runoff from built-up areas protecting them against flooding. Midden heaps and cesspools were used for the disposal of human excreta, and household wastes were often thrown on the streets. The need for systems of water sanitation in large towns became evident during the Industrial Revolution. Urban areas were developing without adequate provision for water supply or for the removal of waste. Accumulations of waste matter and the disposal of wastewater into the surface water channels and gullies resulted in the contamination of water supplies. At their height, epidemics of water-bourne disease such as cholera and typhoid were killing more people than all other causes of death combined. In his report on the sanitary condition of the labouring population of Great Britain (Chadwick, 1842), Chadwick proposed an arterial system of drainage. Faced with the need to secure pure water supplies and to initiate a system of main drainage the First Board of Health was formed, with the Waterworks Clauses Act, 1847 and the Public Health Act 1848 providing the legislative foundation. The existing surface water system was adapted to become a combined system conveying surface runoff and wastewater. The earliest methods of disposal involved land treatment at sewage farms, where the sewage was distributed over an area of land a safe distance from the towns. The principle being to return the nutrients in the sewage to the land.

As the population continued to grow very large areas of land were needed to deal with the volume of wastewater, and to prevent conditions from becoming objectionable. Eventually the volumes of sewage far exceeded the area of land available on which to distribute it and alternative methods of treatment were sought. Sewage treatment works were built for treating sewage, the earliest method used was sedimentation in septic tanks, the sewage sludge being removed and dewatered for use as a manure, whilst the liquid was discharged into the nearest watercourse. The growth in population resulted in the sewerage system, originally built to handle only storm water, becoming overloaded during storm events and the sewage treatment works were unable to process such large volumes of wastewater. Relief to the system was provided by opening the old culvert outlets or constructing new outlets to divert excess water to the nearest ditch or stream, thus avoiding the cost of building larger sewers. These were the first combined sewer overflows an emergency expedient dictated by cost. The primary function of the sewerage system was to convey offensive matter for disposal outside the boundaries of inhabited areas, a rational approach to the combined sewer overflow must have as its aim the continuance of that function at maximum level. Pollution prevention, therefore, comes into direct conflict with the purpose of the overflow. Work by John Snow during the cholera epidemic in London showed that deaths from cholera were very much less in districts that drew their water supply from non-tidal parts of the Thames. As a consequence, the Metropolis Water Act of 1852 forbade abstraction of water for public supply from the Thames below Teddington weir. In 1865 a Rivers Commission was appointed to look into ways of preventing the pollution of rivers. The resulting Rivers Pollution Prevention Acts of 1876 and 1893, however, largely ignored the Rivers Commission's conclusion that pollution prevention was dependent on control of river basins being placed with bodies who were entirely separate from local government. Control was placed in the hands of local authorities who were themselves among the principal polluters of rivers. The Local Government Act, 1888 and the Local Government (Scotland) Act, 1889 transferred the enforcement of river pollution control legislation to county councils, which had no sewerage functions and hence, were not polluters, who created bodies such as the West Riding of Yorkshire River Board and the Lancashire River Board.

The Royal Commission on Sewage Disposal was set up in 1898 and provided recommendations for the setting of combined sewer overflows, its final report being made in 1915. An early report recommended that there should be 'no discharge to a stream until the flow has reached 6 times the dry weather flow'. The fifth report (Royal Commission on Sewage Disposal, 1908) published in 1908 recommended that 'Storm overflows on branch sewers should be used sparingly, and should usually be set so as not to come into operation until the flow in the branch sewer is several times the maximum normal dry weather flow in the sewer. No general rule can be laid down as to the increase in flow which should occur in the branch sewers before the sewage is allowed to pass away by the overflow untreated. The general principle should be to prevent such an amount of unpurified sewage from passing over the overflow as would cause nuisance'. The Rivers Boards Act of 1948 created 34 river boards covering all the watersheds of England and Wales and the Rivers (Prevention of Pollution) (Scotland) Act, 1951, established 9 river purification boards which covered most of Scotland. The 1951 legislation did not apply to Northern Ireland where the 1876 Act remained in force for some time. The Rivers (Prevention of Pollution) Act, 1951, made pollution control more effective by the requirement for effluent discharges to be subject to individual consent setting limits and conditions related to the receiving waters of each location. This only applied to new discharges to non-tidal waters, but was extended by the Rivers (Prevention of Pollution) Act, 1961, and the Rivers (Prevention of Pollution) (Scotland) Act, 1965, to cover existing pre-1951 discharges. The 34 river boards were replaced with 27 river authorities following the Water Resources Act of 1963 and the function of controlling the water resources of their catchments was added to the responsibilities inherited from the river boards.

By the mid-1950s it was apparent that the practice of setting overflows on sewerage systems at 6 DWF, and indeed all aspects of storm discharges required further examination. The Technical Committee on Storm Overflows and the Disposal of Storm Sewage was appointed in 1955 to examine the problem. An investigation of 849 overflows by the Technical Committee found that 370 were unsatisfactory, principally because the weir settings were less than the accepted 6 DWF but also because of the influence of neighbouring overflows and as a result of operating too frequently in wet weather. Their final report (Ministry of Housing and Local Government, 1970) recommended the 'Formula A' approach to the design of Combined Sewer Overflows. The setting of the overflow was expressed as:

$$\text{Setting } (Q) = DWF + 1360P + 2E \quad \text{(litres/day)} \qquad (1.1)$$

DWF = Average daily rate of dry weather flow in dry weather including infiltration and industrial effluent (litres/day)

P = Population

E = Volume of industrial effluent discharged in 24 hours (litres/day)

This approach only accounted for the hydraulic problem of relieving the combined system and did not address the effect of intermittent discharges on the receiving water. One of the main conclusions was that a worthwhile improvement would result if the discharge of gross solids was better controlled. The practice of introducing scumboards to retain gross solid was reported as being only partially successful. Where amenity considerations were of particular importance, the Committee recommended that consideration should be given to the use of purpose-made mechanically-raked screens.

Following this report by the Technical Committee, the Working Party on Storm Sewage (Scotland) was set up in October 1970 to investigate the control and discharge of gross solids from storm overflows, the use and operation of storm tanks and the influence of storm sewage on the selection of sewerage systems and the unit processes of sewage treatment. A report published in 1977 by the Working Party (Scottish Development Department, 1977) found that there was a need for more information on the composition of storm sewage and the main objection from the public to overflows was the fact that they did not prevent aesthetic matter reaching the watercourse. The Working Party recommended, among other things, the use of screens where amenity considerations were of particular importance, stating where screens were installed on CSO's frequent inspections and maintenance was essential.

Reorganisation of the water industry occurred in 1974 following the 1973 Water Act, which abolished the river authorities and created in England and Wales ten multi-functional regional water authorities each associated with one or more of the major natural river basins and responsible for all aspects of the whole hydrological cycle including sewerage and sewage disposal. The Local Government (Scotland) Act

1973 transferred the control of surface water pollution in Scotland to seven new river purification boards and three island councils and also established sewage purification facilities in Scotland under the control of regional councils. In England and Wales, the newly formed regional water authorities were now charged with controlling river pollution but were also the principal polluters of watercourses being responsible for operating and controlling all the sewage treatment works and CSO's, the gamekeeper and the poacher were now on the same side of the fence. In Scotland, however, the river purification boards were responsible for controlling river pollution and the regional councils, administering the sewerage system and sewage treatment works, were the major polluters. The Control of Pollution Act, 1974, superseded the River Acts of 1951, 1961 and 1965, the principle of consent to discharge, however, was retained and the area of control was extended to all coastal waters. In Northern Ireland, the Water Service of the Department of the Environment for Northern Ireland deals with the administration of water supply, sewage treatment and disposal, and water pollution control. Drainage works are carried out by the Department of Agriculture for Northern Ireland.

The cost of maintaining and extending the sewerage system within specific financial restraints brought about the release in 1984 of the Sewerage Rehabilitation Manual (WRc, 1984), which identified the use of CSO's as a potential cost effective means of providing hydraulic upgrading in sewer systems. A growing awareness of urban river pollution saw the introduction, in 1986, of a River Basin Management Programme, set up to extend work on sewer modelling to include storm sewage quality and intermittent discharges on river quality.

The biggest change in the water industry in England and Wales came about by the privatisation of the water utilities in 1989, and following the Water Act of 1989, the formation of a new public body, the National Rivers Authority (NRA), in the autumn of 1989. The services of water supply and sewerage and sewage disposal remained with the water companies, whilst, river basin management and pollution control was transferred from the former water authorities into the hands of the NRA, effectively separating the polluter and the policing agent enabling enforcement of regulations. A statutory framework for the setting and achievement of water quality objectives was established and the WRc Urban Pollution Management group under the umbrella of the Foundation for Water Research continued the research work of the River Basin Management Programme. A considerable amount of this research was aimed at producing standards for intermittent pollution. A major priority of the NRA was to review the terms of the discharge consents for all known CSO's and ensure that any unsatisfactory CSO's were abandoned or improved. The current CSO regulations are discussed in more detail in section 1.4.

1.3 The Role of Combined Sewer Overflows

Combined sewer overflows are structures incorporated into combined sewerage systems. They are designed to allow a proportion of the storm sewage entering the system during storm events to discharge into a watercourse. This relieves a system with inadequate capacity due to hydraulic overloading and reduces the volumes of sewage that have to be dealt with at the treatment works at times of storm. Combined sewer overflows provide a level of protection against storm sewage flooding which can occur either due to hydraulic overloading or system failure (whether due to blockage or due to collapse). However, although combined sewer overflows provide relief for the system, they inevitably result in watercourses being polluted by untreated storm sewage.

A combined sewer overflow structure should, therefore, satisfy the following objectives (Balmforth and Henderson, 1988):

- It should not come into operation until the prescribed flow is being passed to treatment;
- The flow to treatment should not increase significantly as the amount overflowed increases to its design maximum;
- The maximum amount of polluting material should be passed to treatment;

- The design of the overflow should avoid any complication likely to lead to unreliable performance;
- The frequency of operation and volume of spill should not cause significant pollution of the receiving water;
- The overflow should be fully automatic;
- The chamber should be self-cleansing and should be designed to minimise turbulence and reduce the risk of blockage;
- It should have easy, safe access and be properly ventilated with lighting, railings and safety chains provided where necessary;
- It should have minimal maintenance requirements;
- It should have a minimum construction cost;
- New overflows should have a design life well in excess of 50 years

1.4 Present CSO Regulations

Several E C Directives affecting UK controlled waters have been introduced, placing a responsibility on Member States to introduce measures to comply with environmental standards and controls. The UK government is expected to incorporate these measures into current legislation. The E C Urban Waste Water Treatment Directive (UWWTD) (European Commission, 1991) provides the standard for the control of pollutant discharges from CSO's into controlled waters. In the UK all discharges from CSO's into controlled waters require a consent from the NRA under the Water Act 1989. A controlled water is defined under the Act as, all groundwaters, lakes, reservoirs, rivers and canals, estuaries and the first three miles out to sea. The UWWTD places responsibility on Member States to decide on measures to limit pollution of receiving waters due to CSO's. One of the NRA's main duties is to maintain and improve the quality of all the inland and coastal waters under its control. The NRA's interim guidance on consent standards for CSO's from sewerage systems (Morris, 1991) suggested that wherever possible, existing CSO's should:

- not contain significant quantities of trade effluent or 'listed' substances as described in Circular 7/89 and subsequently in the direction to the NRA under

Section 146 of the Water Act 1989 relating to EC Directives on discharges of dangerous substances;

- not cause the receiving watercourse to fail on water quality objectives or affect a Site of Special Scientific Interest;
- receive reasonable dilution so as to prevent nuisance downstream
- have a means of screening or other method of solids separation installed except in extreme cases where this is not technically feasible because of other requirements relating to the siting of the overflow;
- have prescribed in their consent the flow conditions in the sewer, under which the overflow will come into operation;
- have alarmed telemetry systems when sited in sensitive areas.

There are approximately 22,000 CSO's in the UK and it is estimated that up to one third are unsatisfactory. The general guidance notes for consenting intermittent discharges (NRA, 1993) uses the following criteria to define unsatisfactory CSO's.

(i) causes significant visual or aesthetic impact due to solids, fungus and has a history of justified public complaint;

(ii) causes or makes a significant contribution to a deterioration in river chemical or biological class;

(iii) causes or makes a significant contribution to a failure to comply with Bathing Water Quality Standards for identified bathing waters;

(iv) operates in dry weather;

(v) operates in breach of consent conditions provided that they are still appropriate; and/or

(vi) causes a breach of water quality standards (EQS) and other EC Directives.

Aesthetic control of CSO's will be required based upon the combined criteria of Amenity use and Spill frequency (UK WIRL, 1994) as shown in table 1.1:

Table 1.1 Aesthetic Control Requirement for the Discharge of Gross Solids to Freshwaters, Coastal Waters and Estuaries

Amenity Classification	Spill Frequency	Aesthetic Control Requirement
High Amenity • Influences area where bathing and water contact sport (immersion) is regularly practised (eg. wind-surfing, sports canoeing). • Receiving watercourse passes through formal public park. • Formal picnic site. • Shellfish waters.	> 1 Spill per annum	6 mm solids separation
	≤ 1 Spill per annum	10 mm solids separation(2)
Moderate Amenity • Watercourse passes through housing development or frequently used town centre area (eg. bridge, pedestrian are, shopping area). • Boating on receiving water. • Popular footpath adjacent to watercourse. • Recreation and contact sport (non-immersion) areas.	> 30 Spills per annum	6 mm solids separation(1)
	≤ 30 Spills per annum	10 mm solids separation(2)
Low Amenity • Basic amenity use only. • Casual riverside access on a limited or infrequent basis, such as a road bridge in a rural area, footpath adjacent to watercourse. *Non-Amenity* • Seldom or never used for amenity purposes. • Remote or inaccessible area.	Not applicable	Solids separation to be achieved through good engineering design (eg. high-sided weir, stilling pond with or without scum boards or vortex separation)

Notes

1 For spill flow rates up to and including the design flow(3), separation, from the effluent, of a significant quantity of persistent material and faecal/organic solids greater than 6 mm in any two

dimensions. Spill flow rates in excess of the design flow(3) shall be subject to 10 mm solids separation(2)

2 For spill flow rates up to and including the flow resulting from a 1 in 5 year return period storm, separation, from the effluent, of a significant quantity of persistent material and faecal/organic solids giving a performance equivalent to that of a 10 mm bar screen.

3 Where Time-Series data is available, the design flow for 6 mm separation(1) shall be the flow equivalent to 80% of the flow volume that would be discharged in an annual time series.
Where Time-Series data is not available, the design flow for 6 mm solids separation(1) shall be the flow equivalent to 50% of the volume that would be discharged in a 1 in 1 year return period storm.

1.5 Options for Meeting Current Regulations

1.5.1 Hydraulic Control

The hydraulic design of a CSO chamber is based on the setting of the overflow, that is, the restriction of the rate of throughflow for treatment to a pre-determined level. The retention of gross solids is affected by the setting of the overflow which controls the flowsplit

$$\text{Flow Split} = \frac{\text{Total Storm Volume Retained}}{\text{Total Storm Inflow Volume}} \qquad (1.2)$$

The flow in the overflow chamber should be subcritical to achieve good hydraulic control and efficient solids separation. For subcritical flow the water velocity is less than the wave velocity:

$$V < \sqrt{gd} \qquad (1.3)$$

V = Mean flow velocity upstream of weir (m/s)

d = Depth of Flow (m)

g = gravitational acceleration (9.81 m/s²)

Therefore, upstream water levels are affected by the downstream control.

CSO chambers which are the minimum size necessary to achieve adequate hydraulic control will not provide any additional retention of gross solids over and above that provided by the flow split. The modern designs of CSO structures are, however, capable of providing further separation and retention of settleable and floatable gross solids within the overflow chamber over and above that achieved by the setting of the CSO and the flow split. By enlarging and/or improving the design of the CSO chamber gross solids separation can be achieved hydraulically either by settling or by dynamic separation. Where settling is incorporated, two basic designs exist, the high side weir overflow, figure 1.1, and the stilling pond overflow, figure 1.2, both designs need to have sufficiently low inlet velocities to allow separation of solids. The inlet velocities are governed by the inlet pipe size.

The high side weir overflow has a stilling zone in the overflow chamber to ensure that sinkables fall to the invert of the chamber where they are passed forward down the continuation pipe and floatables can rise to the surface, a storage zone is also provided where the floatables can gather and be stored until the storm subsides when they are passed forward to treatment. Stilling pond overflows utilise the same principle as the high side weir overflow by providing a tranquil zone in the overflow chamber, before the overflow weir, to allow sedimentation and floatation of the sewage to occur. The incoming fluid velocity is reduced by increasing the cross section of flow. Dense particles sink and become entrained in the continuation flow, whilst the floatables rise and are trapped in the overflow chamber by scumboards and reverse surface currents in the tranquil region where they are stored until the end of the storm.

In dynamic separation the vortex principle is employed to separate solids. Again two basic designs exist, the vortex overflow with peripheral spill, figure 1.3, and the hydrodynamic separator (Storm KingTM), figure 1.4. In the vortex overflow with peripheral spill a forced vortex is induced in the incoming flow and velocities in the overflow chamber are much higher than in other types of overflow. The rapidly sinking solids become entrained in secondary flows along the bed of the chamber and are passed forward to treatment down a central, vertical continuation pipe in the

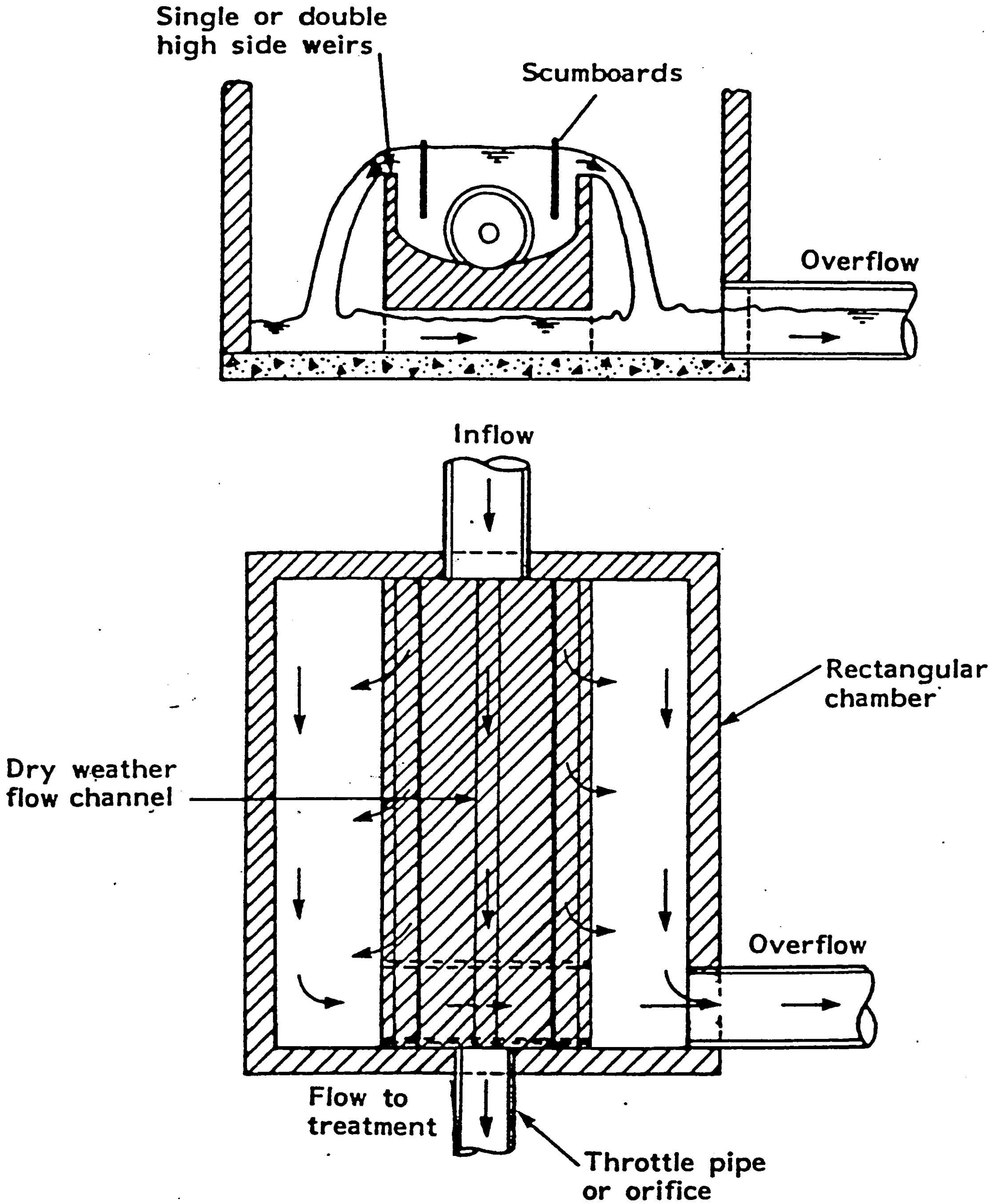


Figure 1.1 High Side Weir CSO

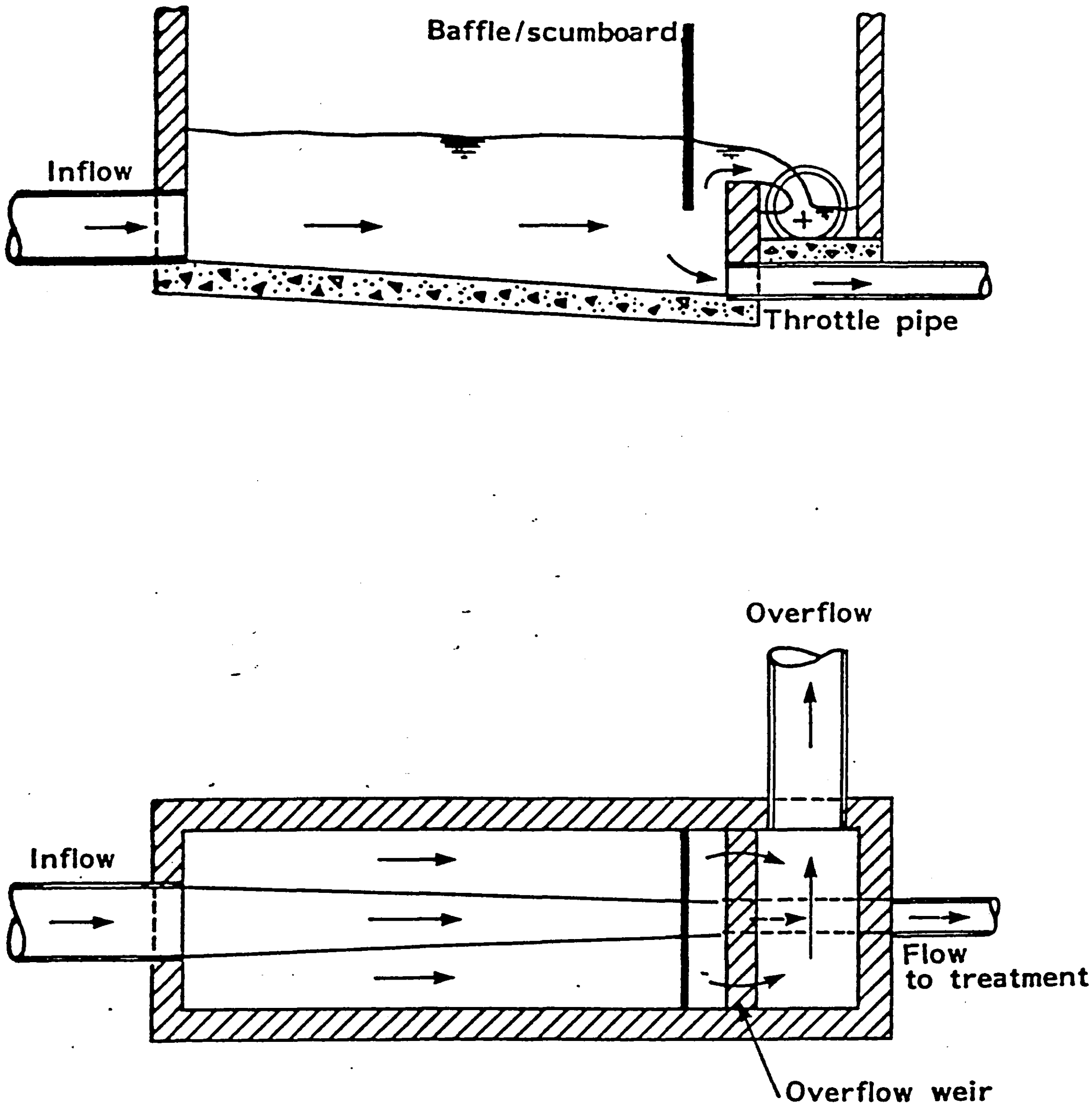
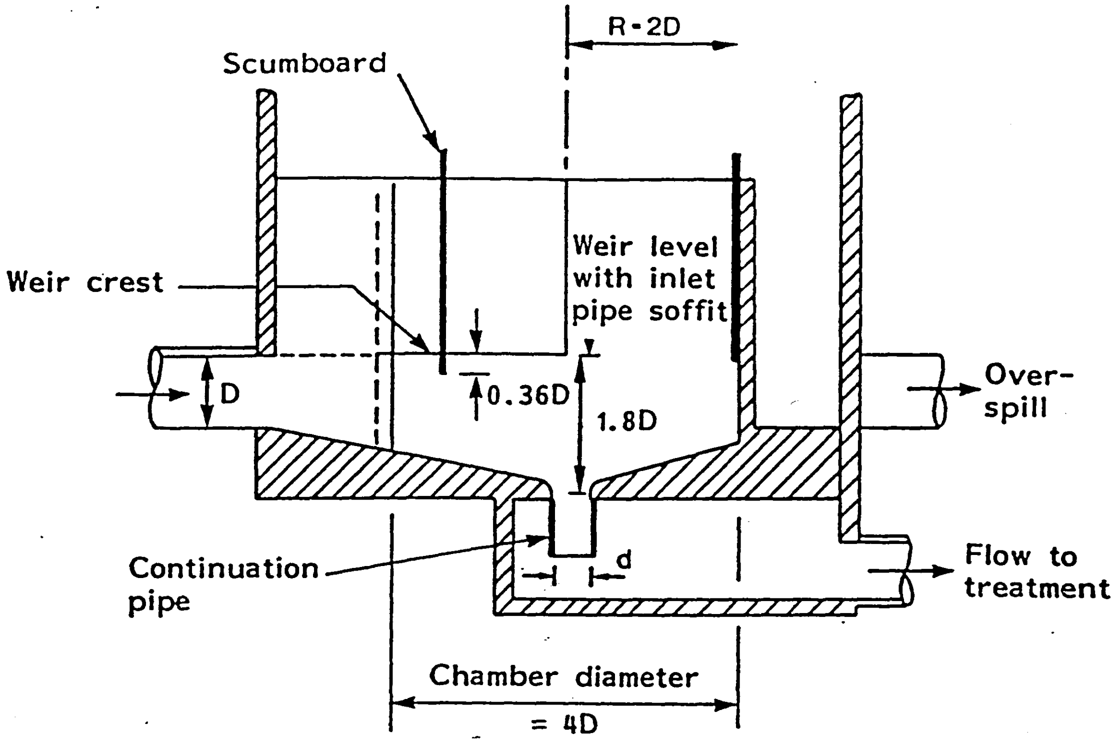


Figure 1.2 Stilling Pond CSO



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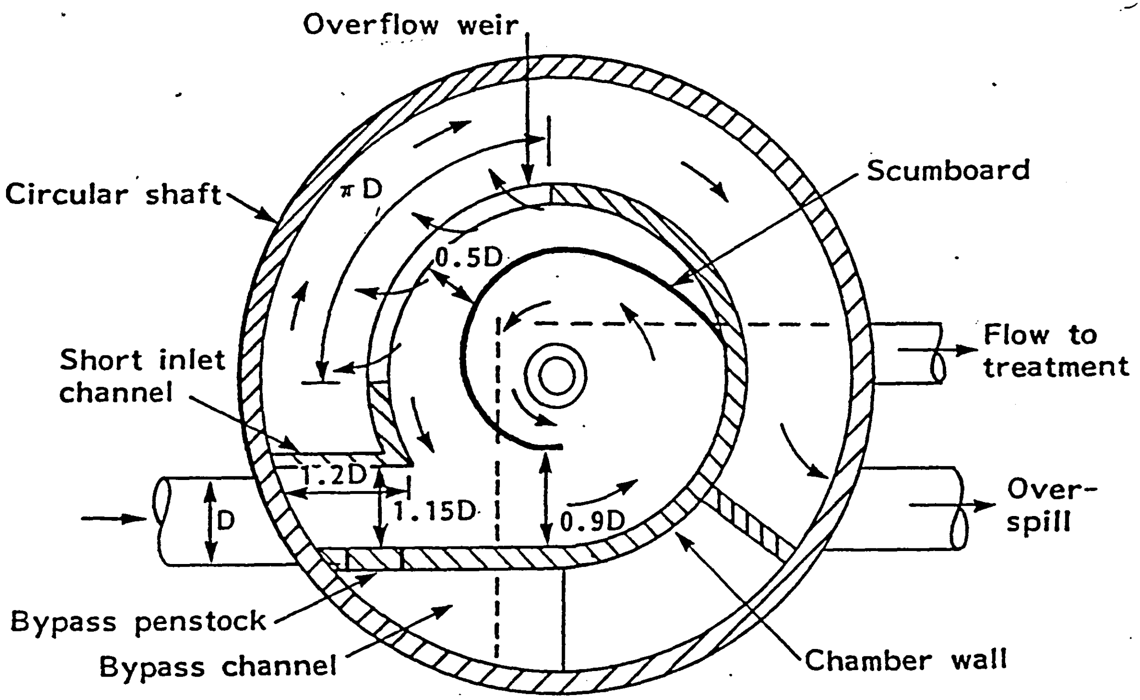


Plan

Figure 1.3 Vortex Overflow with Peripheral Spill

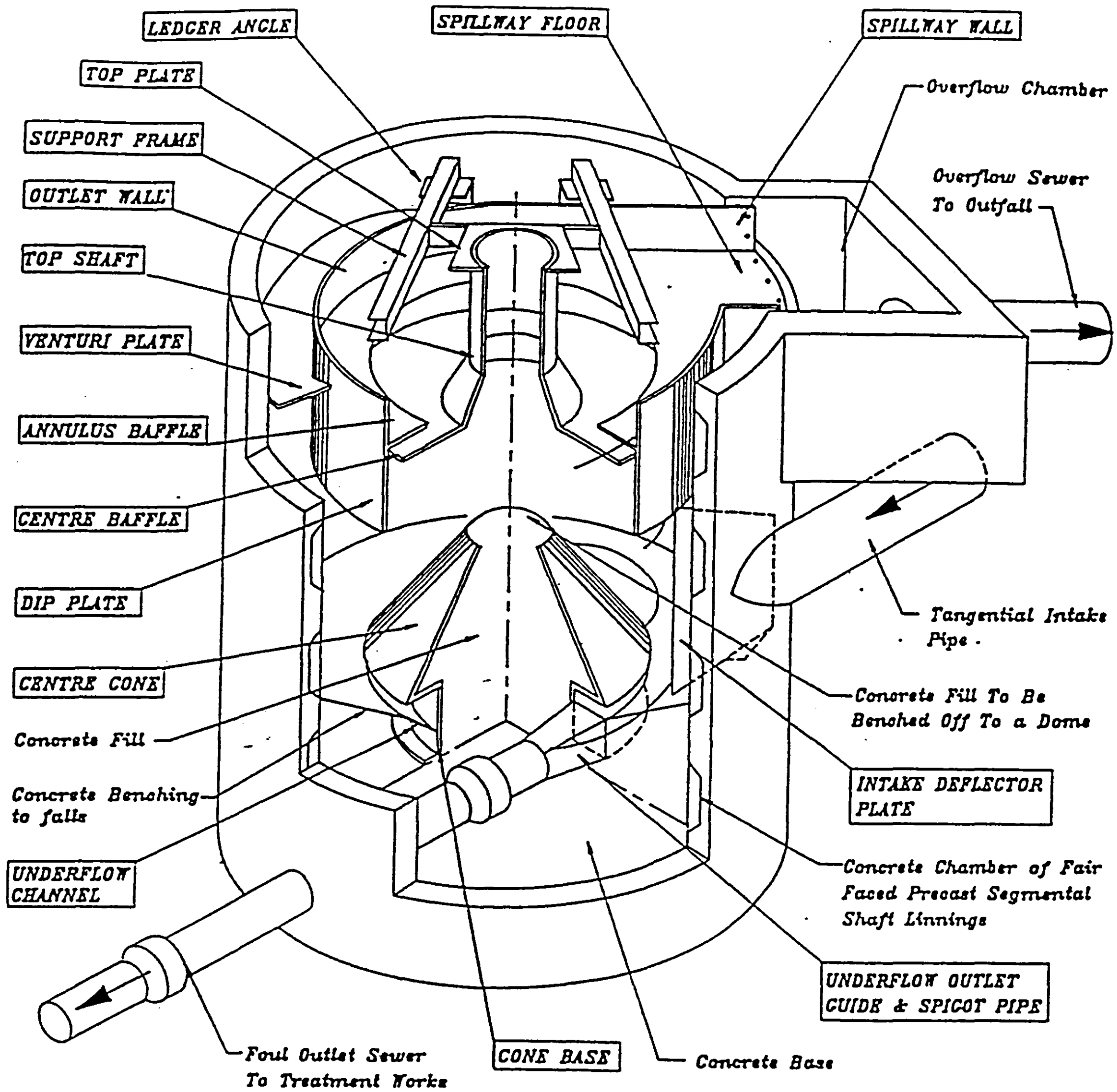


Figure 1.4 Hydrodynamic Separator (Storm King™)

chamber floor, the floatable solids are either trapped by back currents at the surface of the inlet channel or become caught in surface currents which pull them down the central air core of the vortex and into the continuation pipe. A scumboard helps guide the floatables towards the centre and keep them away from the weir. The Storm King™ overflow is a hydrodynamic separator which is used for the removal of gross solids, sediment and floatables for combined sewer overflows, the incoming flow is directed to rotate about the vertical axis of the Storm King™, the settleable solids in the flow tend to spiral downwards around the wall of the vessel and become entrained in the boundary layer on the base which spirals to the centre. Floatable solids spiral upwards and are held between a dip plate and the periphery of the vessel.

The solids retention efficiency of a CSO chamber depends on the type of chamber, its volume, the rate of inflow and the rate of continuation flow. None of the CSO designs effectively separate neutrally buoyant solids over and above the flow split, i.e. if 20% of the flow goes to treatment and 80% to the river, 20% of the neutrally buoyant solids will go to treatment and 80% to the river.

1.5.2 Quantitative Control

The setting of a CSO (defined as the flow at which first spill occurs) influences the frequency of operation, the volume discharged to the watercourse, and ultimately the pollution load on the receiving watercourse. By reducing the frequency and volume of spill of the CSO, the subsequent pollution load on the receiving watercourse is reduced and the solids separation required by the current guidelines (NRA, December 1993) may also be reduced. For example, if a CSO discharges more than 30 times per annum to a watercourse of medium amenity, then for spill flows up to and including the design flow, 6 mm solids separation must be provided, with 10 mm solids separation being provided for spill flow rates in excess of the design flow. If the frequency of spill could be reduced to 30 spills of less per annum then only 10 mm solids separation needs to be provided for the spill flow.

The setting of a CSO is controlled by restricting the flow from the chamber into the continuation pipe with a throttle device. Types of throttle include the orifice plate throttle, adjustable penstocks and gates, throttle pipes and vortex regulators (hydro-brakes). The simplest form of throttle is the orifice plate and consists of a steel plate with an orifice cut out, which is fitted over the entry to the continuation pipe. The size of the orifice is dependent on the degree of restriction necessary to achieve the overflow setting. Orifice plates may be prone to blockage causing premature operation of the overflow. To minimise the risk of this occurring the minimum opening size should be equivalent to a 200 mm diameter circular aperture. Adjustable penstocks operate on the same principle as the orifice plate except the setting of the overflow can be altered by adjustment of the penstock. The throttle pipe provides a greater degree of control over the passed forward flow than the orifice plate. With a larger diameter opening, blockage of the throttle pipe is less common. The throttle pipe is, however, more costly to construct than the orifice plate. Vortex regulators are usually constructed of steel and fit over or into the entrance of the continuation pipe. Vortex regulators provide a greater degree of throttling than other types of throttles of the same sized opening giving a smaller throughflow for a given head. This is achieved by the formation of a cone of air which restricts the flow passed forward to treatment. End weirs, side weirs, siphons or partial or full circular weirs are employed to discharge the excess flow to the receiving water. The height and length of each type of weir and the size, number and location of the siphons will also affect the setting of the overflow.

An effective way to prevent pollutant discharge is by the provision of storage within the sewerage system or at the CSO. The storage volume reduces the frequency of overflow operation, delays the time to first spill, reduces the volume of spill and, therefore, the pollutant load discharged to the watercourse. Downstream flooding can also be alleviated by the provision of storage. The storage volume can either be provided on-line or off-line with either rectangular tanks or oversize pipes. Research has shown (Thornton and Saul, 1985) that the majority of the pollutant load arrives at the CSO chamber in the early stages of the storm. If an on-line storage volume is to be incorporated it should be constructed downstream of the overflow weir to retain the first flush pollutants which will be passed forward to treatment. The less polluted flow in the latter part of the storm will be passed over the weir.

1.5.3 Mechanical

CSO chambers are generally not capable of separating neutrally buoyant gross solids other than in the proportion of the flow split. Because of the need to meet consent standards for the discharge of gross solids, it is likely that in many cases some form of physical control of gross solids in the spill flow will be required. CSO screens are intended to prevent gross solids which are not retained in the sewer system by hydraulic separation from reaching the receiving watercourse. The performance of CSO chambers may also be enhanced by fitting screens, if this is considered necessary and is practical and cost effective. It may be, for example, more cost effective to provide screens to achieve 10 mm solids separation rather than introduce or increase storage in the system or improve the CSO chamber design. The retention efficiency of a screen is defined as:

$$\text{Screen Retention Efficiency} = \frac{\text{mass of gross solids retained by screen}}{\text{total mass of gross solids presented to screen}} \times 100\ \% \qquad (1.4)$$

1.6 Objectives of Good Screening Practice

1.6.1 Efficiency

The retention efficiency of the screen as defined above is one of the most important objectives. A screen which fulfils all the other objectives but has a very low retention efficiency, e.g. 10% is not achieving the primary objective of a screen, i.e. to retain gross solids. The material used for the actual screening media must be strong enough to withstand the spill flowrates passing through it. Bar screens become more fragile as the bar spacing decreases, figures 1.5 and 1.6, since as the gap narrows so does the width of the bars to maintain open area. This may lead to solids being forced through the screen as the bars distort or buckle through lack of strength.

Figure 1.5 Bar Screen (15 mm spacing)

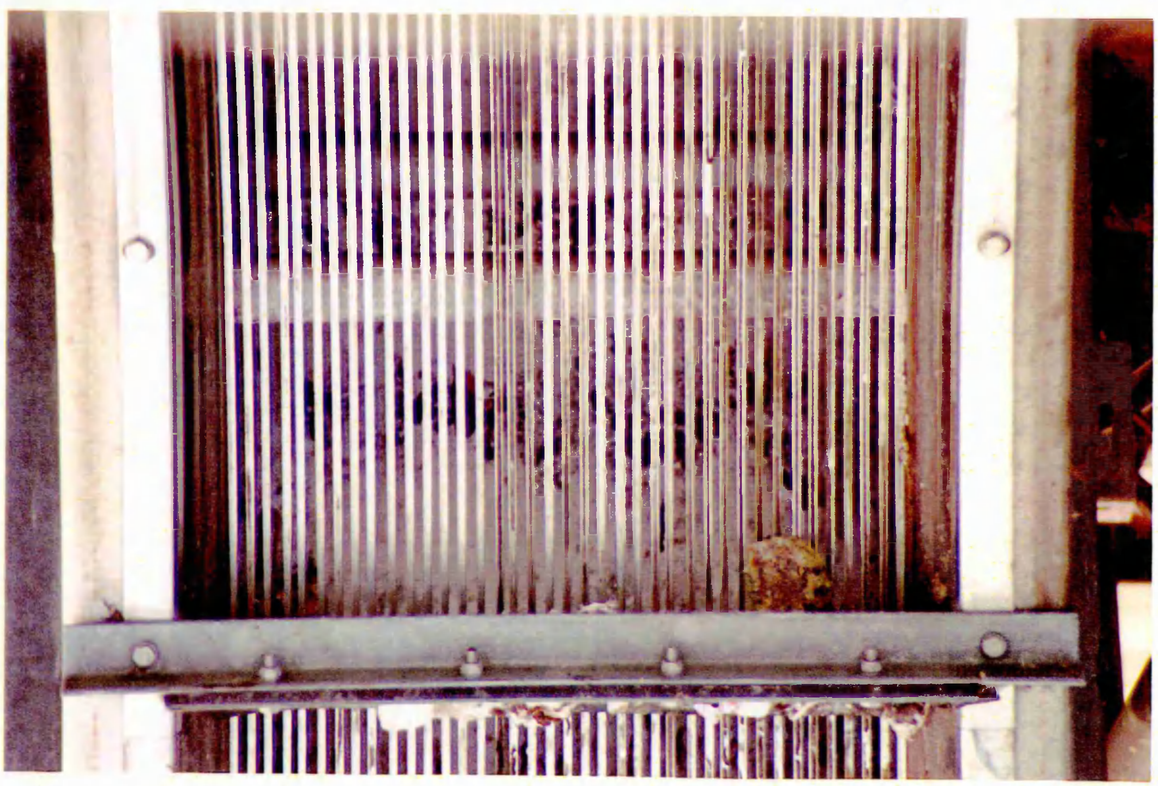


Figure 1.6 Bar Screen (6 mm spacing)

Screen retention efficiency can be reduced from the carry over and pass through of gross solids. Blockage of wash water spray bars/jets can give rise to carry over of gross solids where debris not removed from the screen drops into the flow downstream. Gross solids remaining on the screen after cleaning may be washed forward into the flow downstream of the screen.

1.6.2 Hydraulic Performance

Fine screening may impose head conditions upstream sufficient to cause premature operation of upstream overflows or may reduce the flow velocity to an extent that grit is deposited immediately upstream of the screen faces. The flow conditions and upstream system may dictate the choice of screen at a particular location. If a site has a history of grit accumulation, then a screen which is adversely affected by grit deposits will not be suitable. If the upstream system has a steep gradient which produces high inlet velocities then a screen with a brittle screening media may not be suitable.

1.6.3 Cleaning and Disposal of Screenings

The method chosen for cleaning the screens must be efficient to reduce not only carry over and pass through of gross solids but also hairpinning where fine and fibrous material becomes wrapped around the wires of bar screens and bridges the gap between the apertures of perforated screens. Severe hairpinning may require manual cleaning and often the gross solids need to be cut free by maintenance personnel. A complex cleaning system is more prone to wear and attack from the various chemicals found in sewage. Wear or play in the raking mechanism of some screens results in poor meshing of the tines with the screen and a subsequent reduction in screening efficiency. The screen must be able to handle stones, grit and other debris without damaging the cleaning/raking mechanism. If wash water is required for cleaning, the volume and pressure of the wash water required by the screen may not be readily available and the use of potable water could produce high running costs. Inefficient cleaning of screen installations may result in gross solids being deposited on weirs and collecting in channels, they may also jam valves and penstocks. Over a period of time gross solids may accumulate on parts of the screen installation. Poor engineering design on some screens means the brushing mechanisms deposit the screening onto other brushes or wash water spray bars/jets, blocking the holes and causing the carry over of screenings from inefficient cleaning. Screens should ideally be self-cleaning without the need for wash water and there should be an automatic emergency bypass should blockage, blinding or failure of the screen occur.

If the gross solids retained by the screen are not returned back into the flow for treatment the method of disposal needs to be considered. For disposal to certain landfill sites screenings must be washed and dewatered which may require additional plant and room to house this, in addition to the increased running and maintenance costs. A number of combined sewer overflows are in remote locations or located beneath busy highways making access difficult so removal of screenings for disposal can be expensive and time consuming as well as unpleasant for the operators responsible.

1.6.4 Operation

The screen needs to operate efficiently and the actual screening mechanism must be reliable. Due to the design of combined sewer overflows, screens installed within combined sewer overflows only operate intermittently. Combined sewer overflow screens are prone to failure due to the seizure of moving parts after long dry periods when the screens are not working. Because of this many screens now have a daily test cycle which they operate even during dry weather. The screen needs to be sufficiently robust to achieve the necessary design life without major failure. The amount of technical back-up received from the manufacturer is important if operating problems are incurred. This is especially important for combined sewer overflows which discharge to high amenity watercourses where screen failure would result in visible pollutants entering the watercourse and/or flooding upstream. The method of activating the screening mechanism must be reliable, screen installations are usually activated by probes which start the screen once the level within the chamber reaches them or by an ultrasonic device set to activate the screens at a pre-set water level. The mechanical drive of the screen installation must be able to operate in an atmosphere of high humidity and/or toxic gases e.g. hydrogen sulphide which can be found in combined sewer overflows, i.e. it must be intrinsically safe. A separate drive may be required for the cleaning mechanism so the CSO must have room to accommodate this.

The screen installation may have to be retrofitted into an existing CSO. The size and weight of the screen and the position of the centre of gravity of the screen can pose handling problems for installation. Where retrofitting does occur there should be a method of adjustment after installation to ensure a good seal with the channel sides, channel bed etc.

Maintenance and reliability are important not only because of ongoing cost implications but also environmental considerations from possible increased pollution from screen failure. The screen installation should be easily accessible for maintenance and servicing. The accumulation and settlement of grit around the screen may cause the wearing of component parts of the screen, consequently increasing the cost of maintaining the screen. The accumulation of grit at the base of combined sewer overflow screens can be problematic as limited access can make removal difficult and high pressure water jetting is not always possible.

1.7 Types of Screens

1.7.1 Fixed Bar Screens

These screens were some of the earliest to be introduced into CSO's and are still found on some CSO's today. They are simple hand-raked gratings of straight bars usually circular in cross-section which are normally vertically mounted on the CSO weir. Blockage of this type of screen is common due to infrequent cleaning by maintenance personnel. Fixed bar self cleansing screens are also installed on

CSO's, they are supposedly streamlined to avoid blockage and remove the need for maintenance. However, this type of screen like the other fixed bar screens frequently blind and cause blockages.

1.7.2 Mechanically Raked 'D'-Screens

This design has been around since the turn of the century and is the commonest screen found on CSO's today. The use of rectangular bars arranged in a semi-circular profile enabled a raking mechanism without chains and sprockets to be developed. The screens are generally raked by a rotary two-rake mechanism, the rake tines passing through the screen bars from the upstream side of the screen, figure 1.8. As with the fixed bar screens the semi-circular bar screens or 'D'-screens are located on the crest of the CSO weir, the flow passing downwards through the screen by gravity. The velocity passing through weir mounted screens is usually high, encouraging solids to break up and material to wrap around the screen bars making raking difficult. The screens are either transverse to the direction of flow with the gross solids raked with the flow, generally in a stilling pond type CSO, figure 1.9, or parallel to the direction of flow with the gross solids back raked into the approaching flow in the case of a high side weir CSO, figure 1.10. The latter arrangement is not favoured due to the possibility of a proportion of the solids being raked repeatedly resulting in either solids collecting and blocking the screen or becoming sufficiently comminuted to pass through the screen. In longer weirs the screen is built up in bays.

1.7.3 Inclined Straight Bar Screens

Like the semi-circular bar screens, this type of screen has been around since the turn of the century but unlike the semi-circular bar screens has only recently been installed on CSO's. The first straight bar screens like the fixed bar screens were manually raked vertical wrought-iron gratings but the introduction of mechanical raking necessitated inclination of the bars to provide a constant pressure of engagement of the raking mechanism. Two basic designs exist, the front mechanically raked fixed bar screen, figure 1.11, and the back mechanically raked fixed bar screen, figure 1.12.

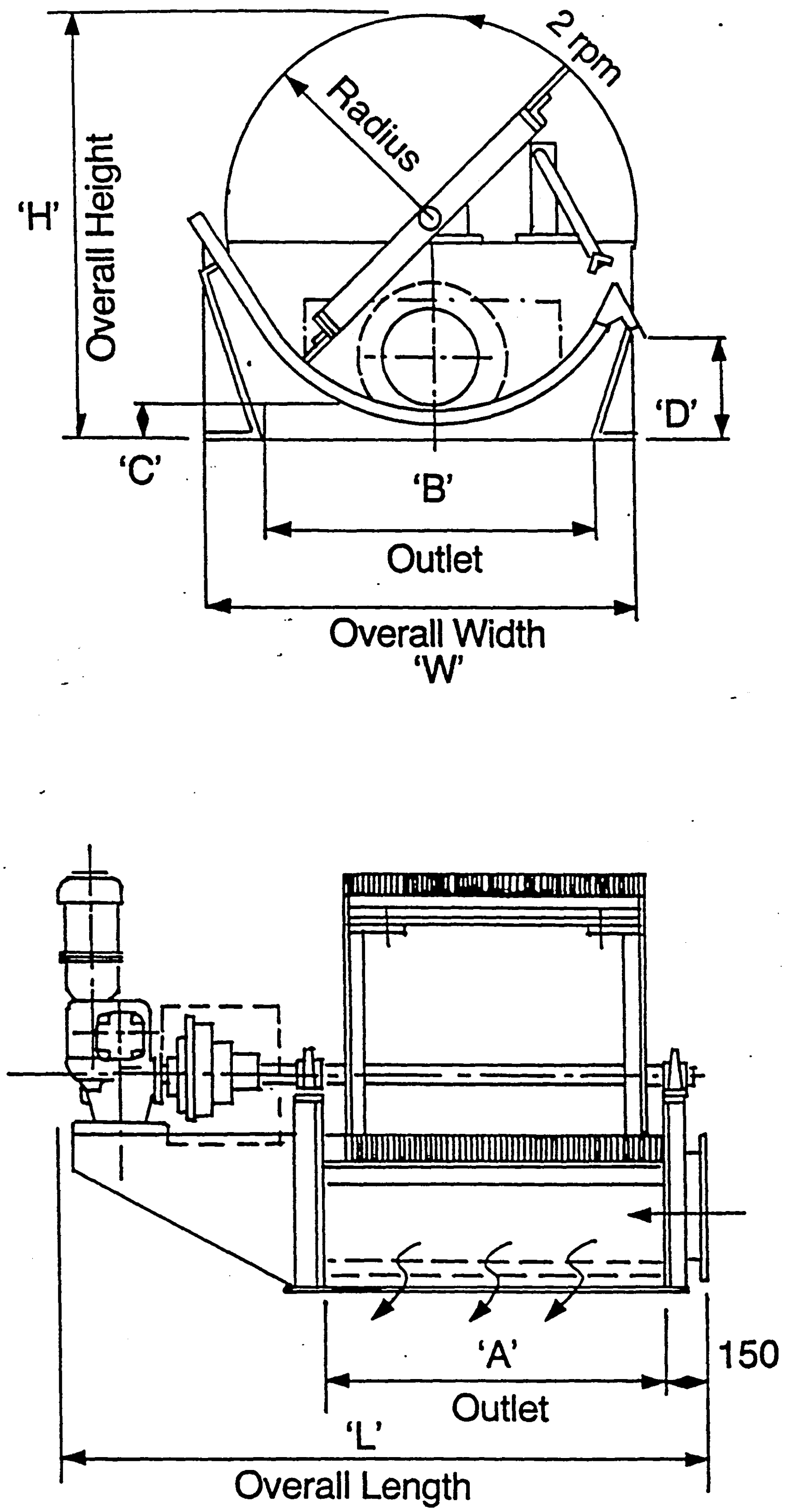


Figure 1.8 Mechanically Raked 'D'-screen

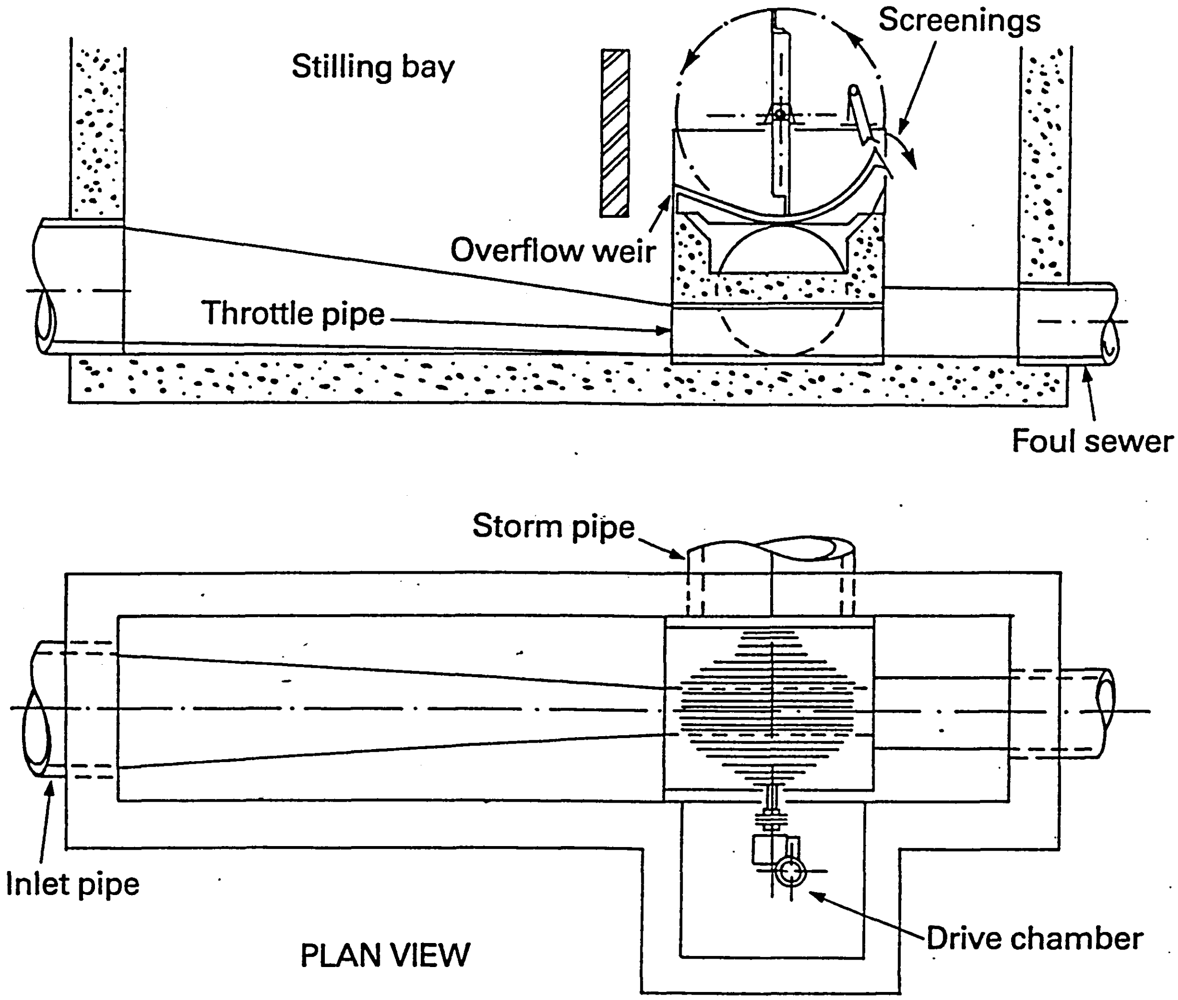


Figure 1.9 Stilling Pond CSO with D-screen

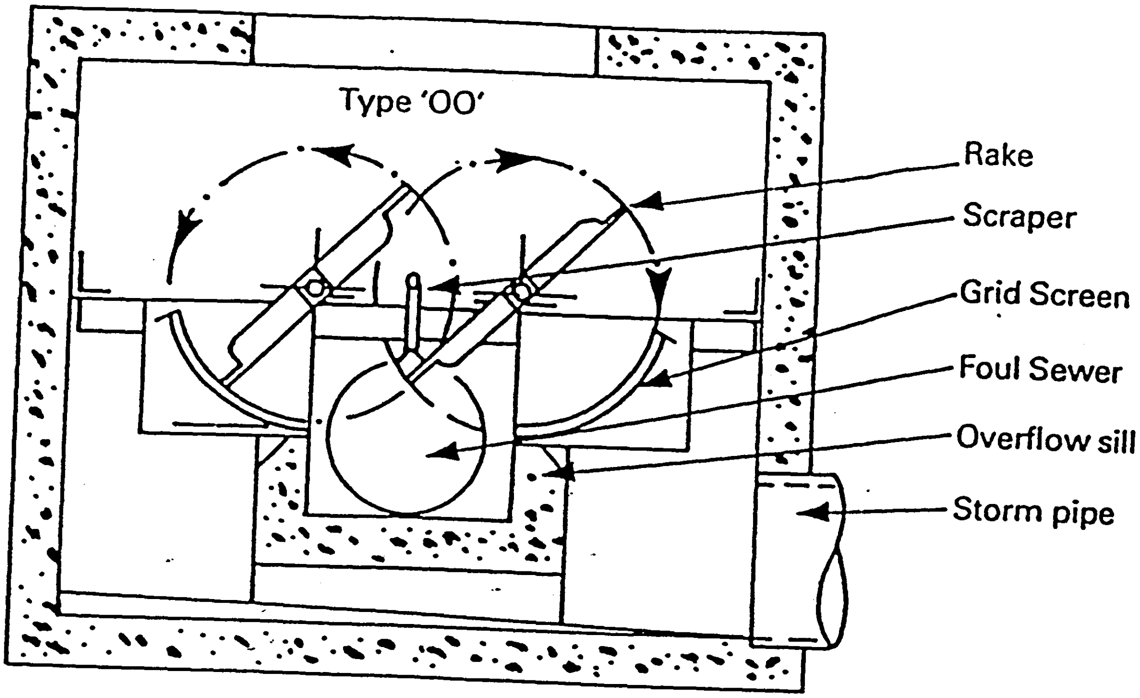
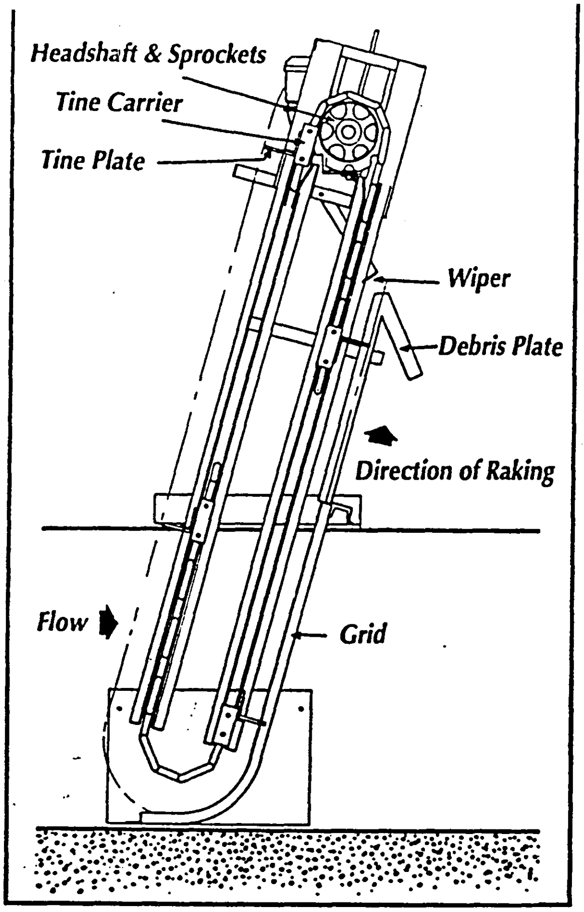


Figure 1.10 High Side Weir CSO with D-screen



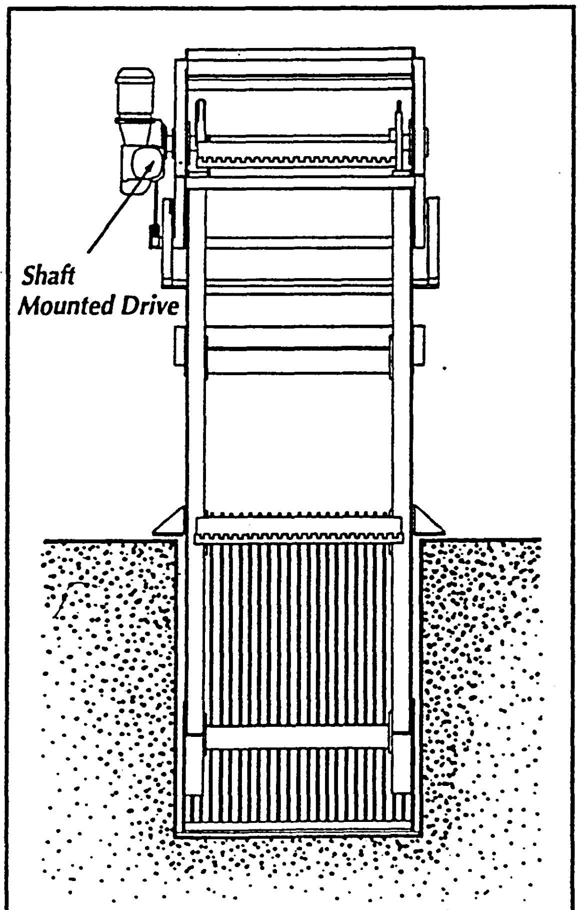


Figure 1.11 Inclined Straight Bar Screen (front mechanically raked)

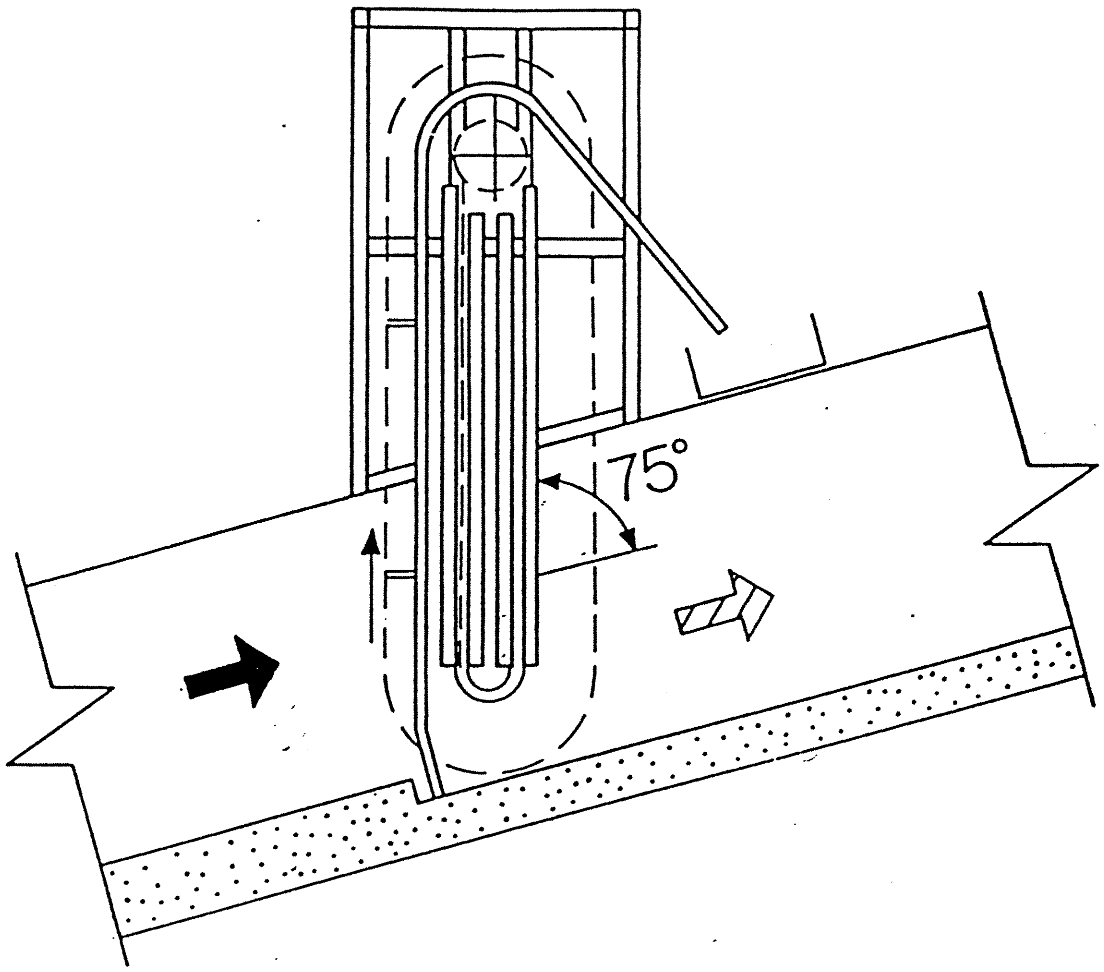


Figure 1.12 Inclined Straight Bar Screen (back mechanically raked)

The raking actions of both screens utilise the same endless chain principle. however, the location of the raking mechanism differs. The inclined straight bars of each screen are fixed and continuously raked by a number of sets of tines mounted on a moving endless chain. Where back raking is used the screens generally have a curved top section so gross solids are carried over the top and dropped into a hopper on the downstream side of the screen. The accumulated gross solids are lifted up the face of the screen by the rake tines being inserted through the screen bars from the downstream side of the screen. With a front raking mechanism the gross solids discharge point is again at the top of the screen but a scraper forces the gross solids into a collection receptacle. The insertion of the rake tines into the collected gross solids from the front of the screen forces some gross solids through the bars reducing the overall efficiency of the screen. The carry over and pass through of gross solids is common with this type of screen, an inefficient cleaning mechanism can carry over gross solids which may then drop into the flow downstream of the screen, and gross solids remaining on the screen face after cleaning can be washed forward into the flow downstream, effectively being passed through the screen. Another design has fixed bars and incorporates a mechanical arm for raking the screen clean instead of utilising the endless chain principle. The cleaning rake is inserted through the bars from the downstream side of the screen on its upward travel and collects the gross solids from the screen bars elevating them to a discharge chute, the rake is then retracted on its downward travel. Inclined bar screens are positioned in the spill channel of the CSO away from the weir which allows a greater cross-section of flow to be screened with lower velocities.

1.7.4 Rotating Drum Bar Screens

The first drum screen was reported to have been patented by Jennings in 1868 (Cookman, 1986) and described as a 'hollow rotating screen'. Rotating drum bar screens are constructed of circular steel bars fastened together to form a cylinder, this is supported on roller bearings to enable rotation about its central axis, figure 1.13. The drum is usually partially submerged in the CSO chamber and the flow enters

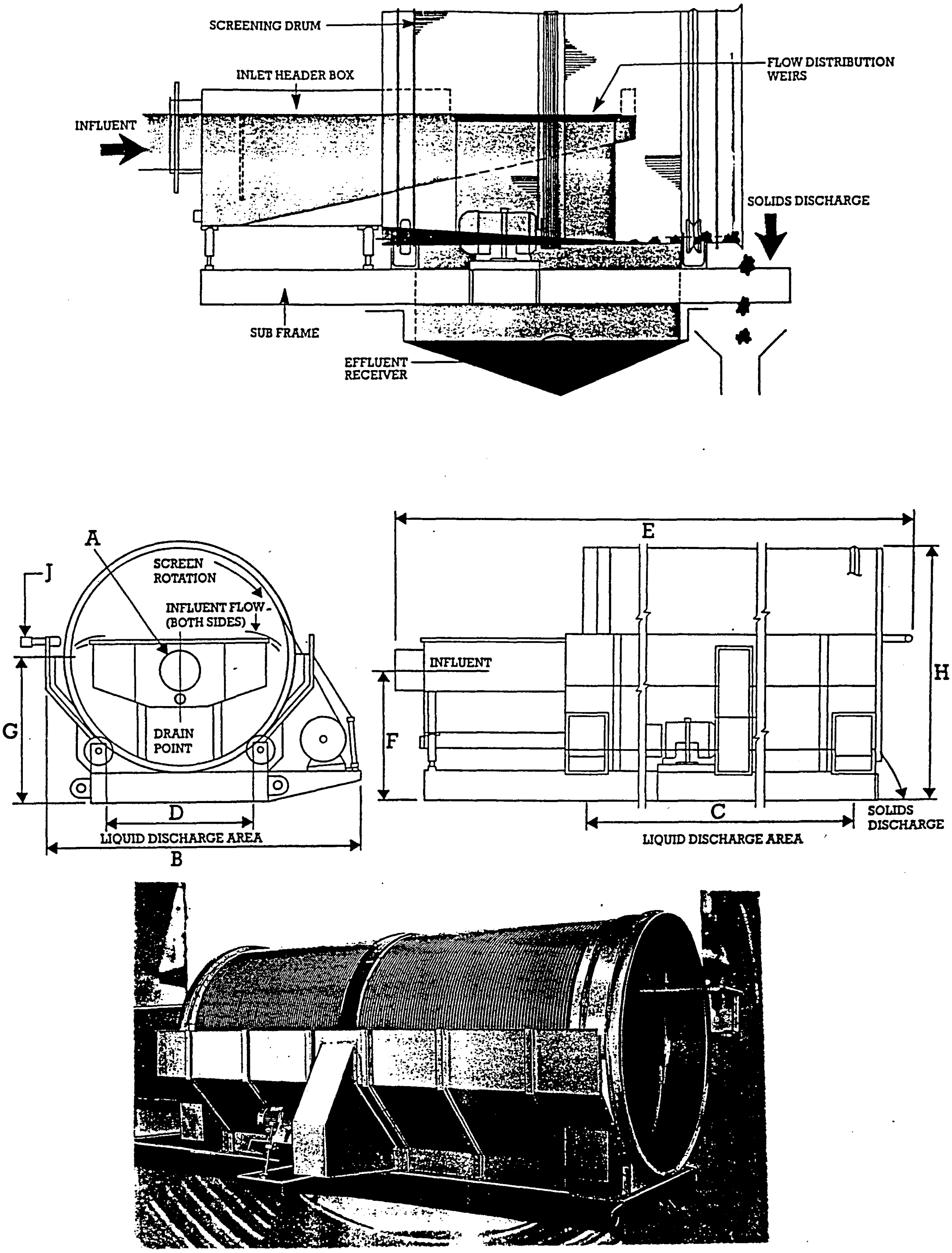


Figure 1.13 Rotating Drum Bar Screen

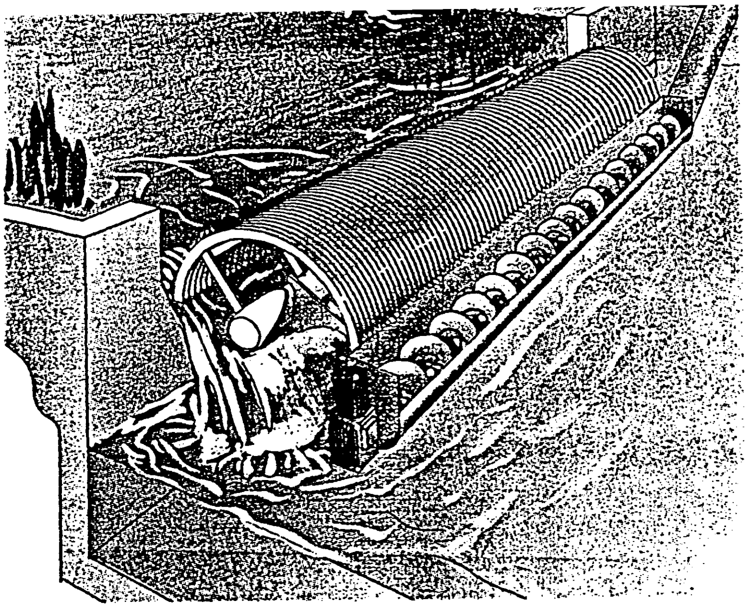
either from a single side or from both sides and passes radially from the inside to the outside of the drum being discharged axially through holes in the side wall of the chamber. The gross solids are returned to the flow in the chamber by a fixed rake.

A more recent development of this screen is the externally-fed rotating drum bar screen, figure 1.14. The screening drum consists of semi-circular bars and is situated horizontally behind the CSO weir. The water flows through the screen bars and gross solids are caught on the outer surface of the drum. A rotating rake fixed to a centre shaft inside the drum collects the gross solids with the aid of rake tines and transports them out of the flow over the top of the screen into a collection hopper.

Another design available is the rotating vertical drum screen which comprises a number of cast iron cylinders which have fine continuous grooves machined through the cylinder walls, figure 1.15. The screening drums are cleaned with combs, the teeth of which penetrate beyond the depth of the groove. The collected gross solids are lifted from the flow to a discharge chute above the screen.

1.7.5 Mechanically Raked Weir Mounted Straight Bar Screens

The mechanically raked weir mounted straight bar screen is a relatively recent design which originates from Switzerland, figure 1.16. As its name suggests this screen is located on the CSO weir and can be mounted vertically or installed horizontally as an upward or downward flow screening system. The straight bars of the screen are manufactured from stainless steel and the raking tines are high density plastic. The cleaning mechanism is operated on a linear basis with the raking tines reciprocating along the screen face in sliding blocks, arranged on the downstream side. The collected gross solids are transferred to the downstream end of the screen, where they are free to disengage the mechanism and rejoin the forward flowing, foul flow. Adhering gross solids on the cleaning combs are removed by a scraper at both ends.



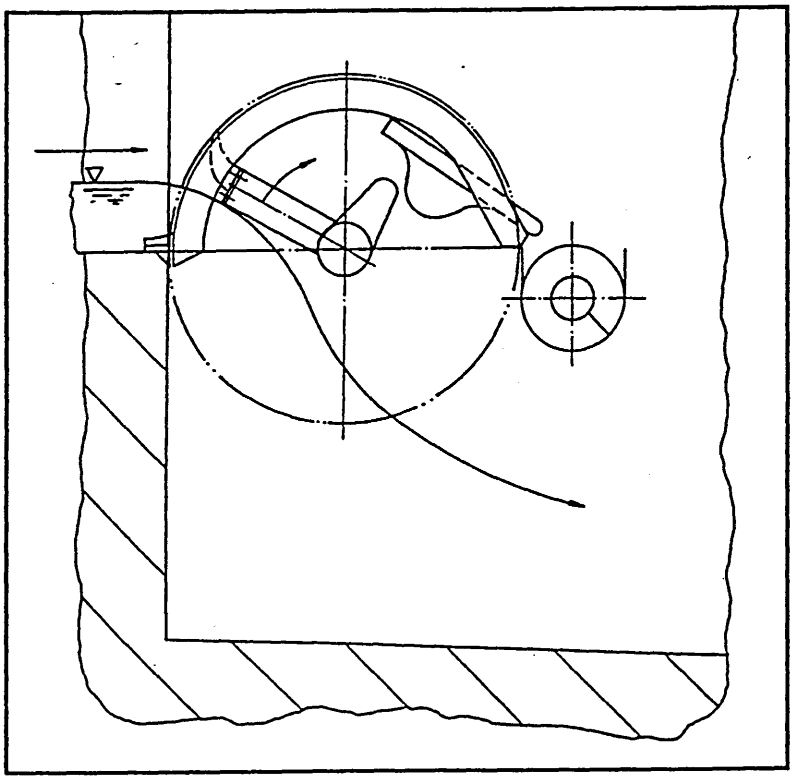
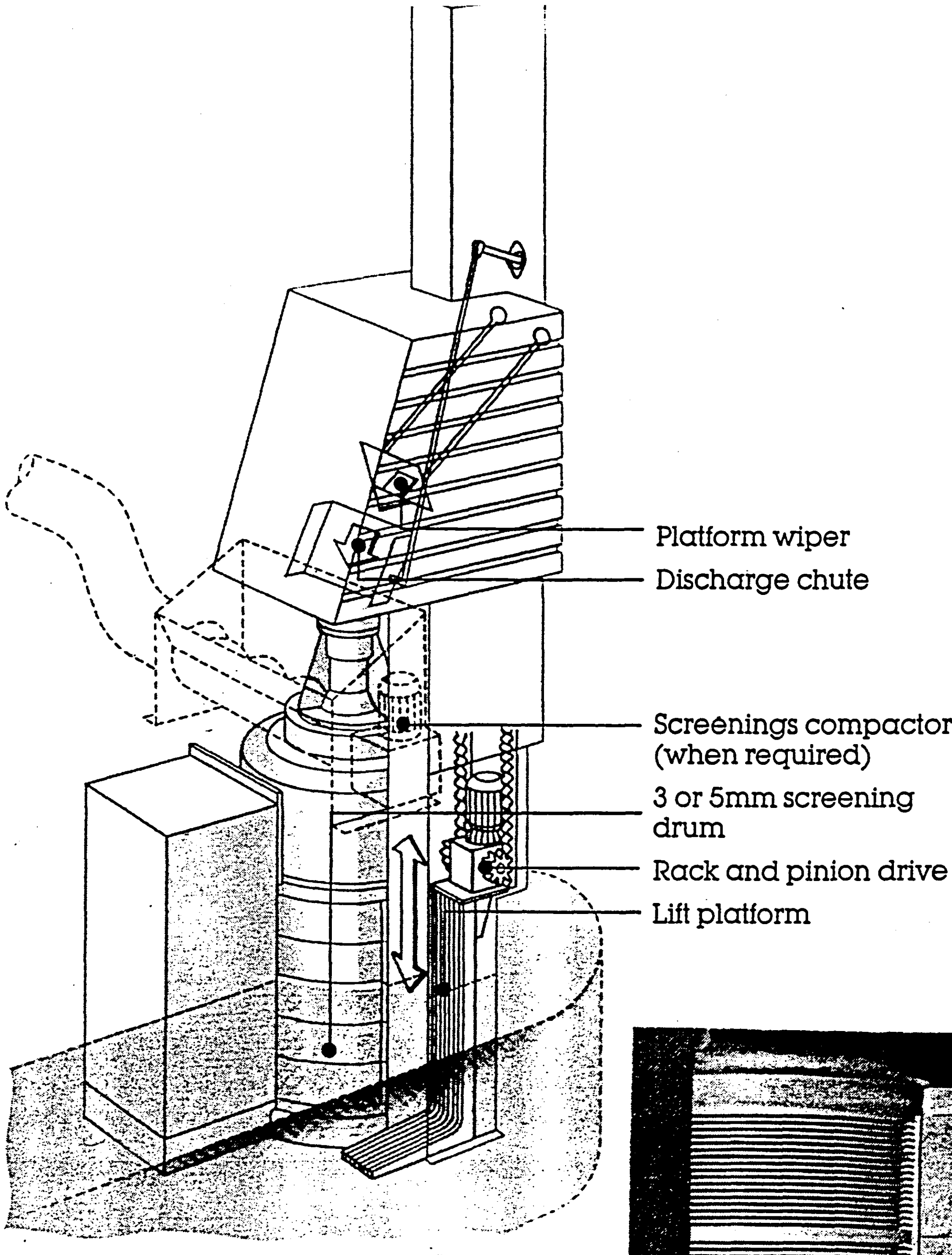


Figure 1.14 Externally Fed Rotating Drum Bar Screen



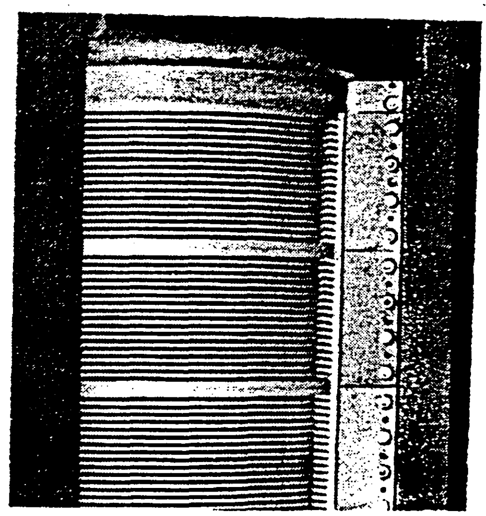
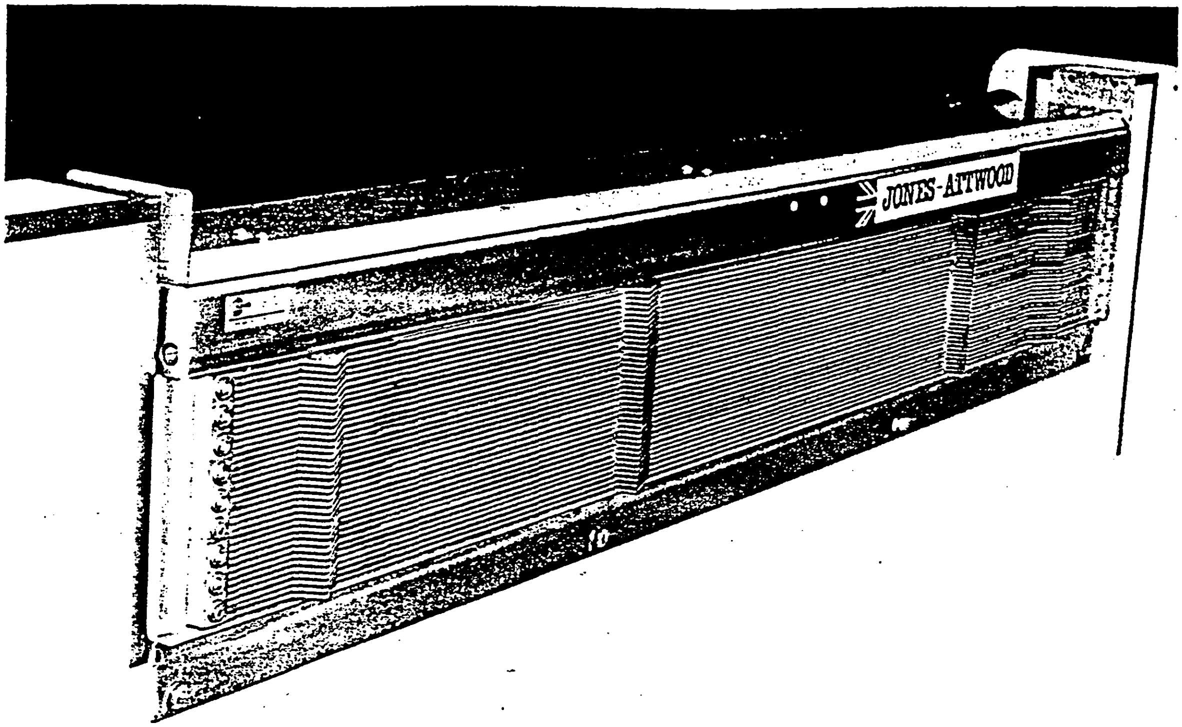


Figure 1.15 Rotating Vertical Drum Screen



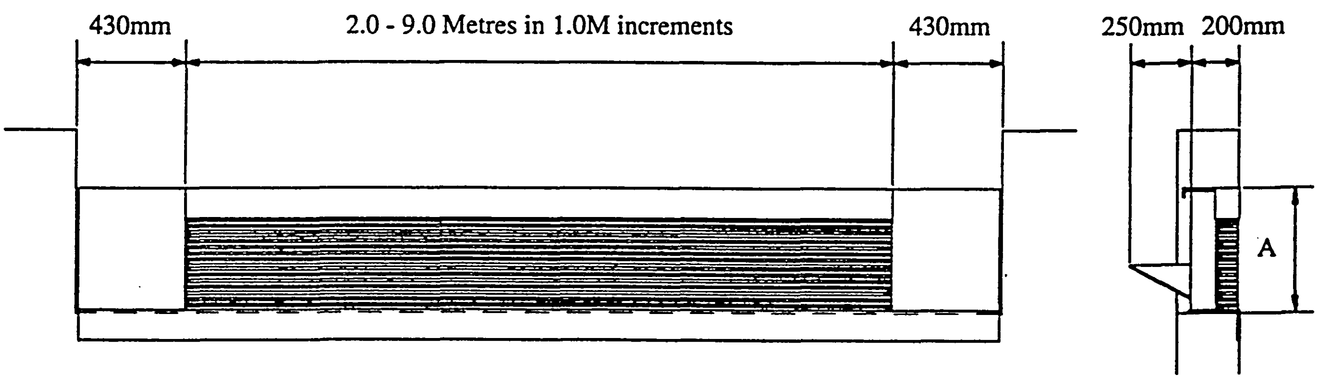


Figure 1.16 Mechanically Raked Weir Mounted Straight Bar Screen

1.7.6 Slotted Belt Screens

The inclined slotted belt screen was introduced to the UK from Japan and incorporates a combined slot and rake system, figure 1.17. The slot and rake elements are assembled horizontally and vertically on a series of parallel shafts to form an endless continuously moving belt which collects, conveys and discharges the gross solids. The rake elements discharge the gross solids at the top of the screen and a rotating brush arrangement is incorporated to clean the rakes. This type of screen is installed in the spill channel of a CSO like the inclined bar screens.

Other designs consist of a continuously moving plastic slotted belt which intercepts the solids and elevates them to the discharge point, figure 1.18. The gross solids drop off the face of the belt at the top of its travel and a rotating brush assembly and backwash aid the cleaning of the screen.

1.7.7 Fixed Mesh Screens

These screens are similar to the fixed bar screens except they have a steel grid instead of bars. Again blockage is common and blinding of the screen is more rapid than that of the bar screen. Regular manual cleaning is essential.

1.7.8 Mesh Sacks

Disposable and extending mesh sacks are more commonly found at sewage treatment works where personnel are on hand should the sacks blind and cause a blockage. They may be used as a short-term solution to a localised problem in CSO's. Using a trash screen, mesh sacks can be hung on the overflow weir, figure 1.19. However, they quickly blind and should be replaced after each storm event. Mechanical mesh sack agitating systems are also available which are designed to continuously wash the contents of the sacks, making their disposal less of a problem than unwashed gross solids, figure 1.20. The extending mesh sacks are fitted to the spill pipe of a CSO, figure 1.21. As the mesh blinds the force of the water extends the

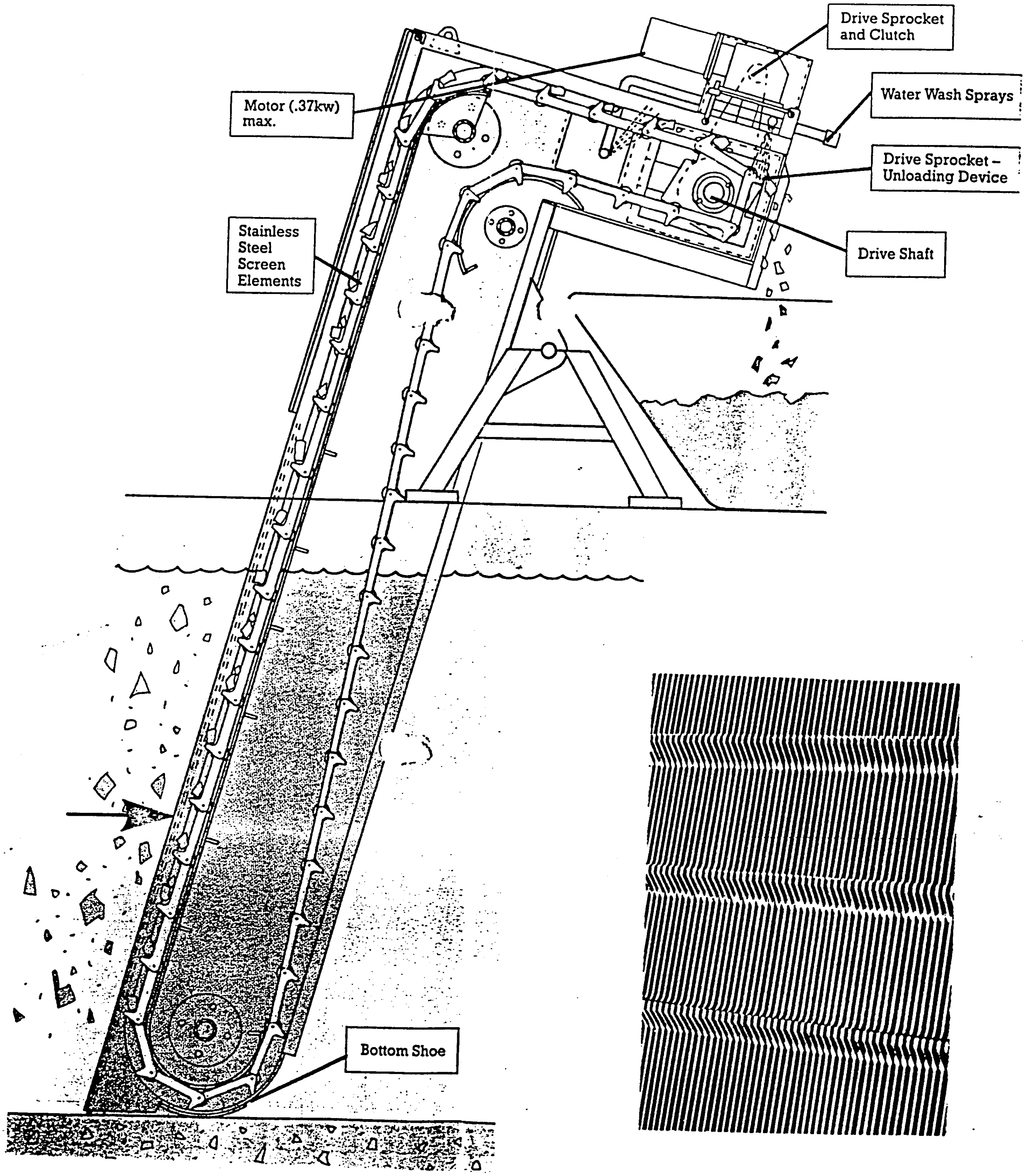
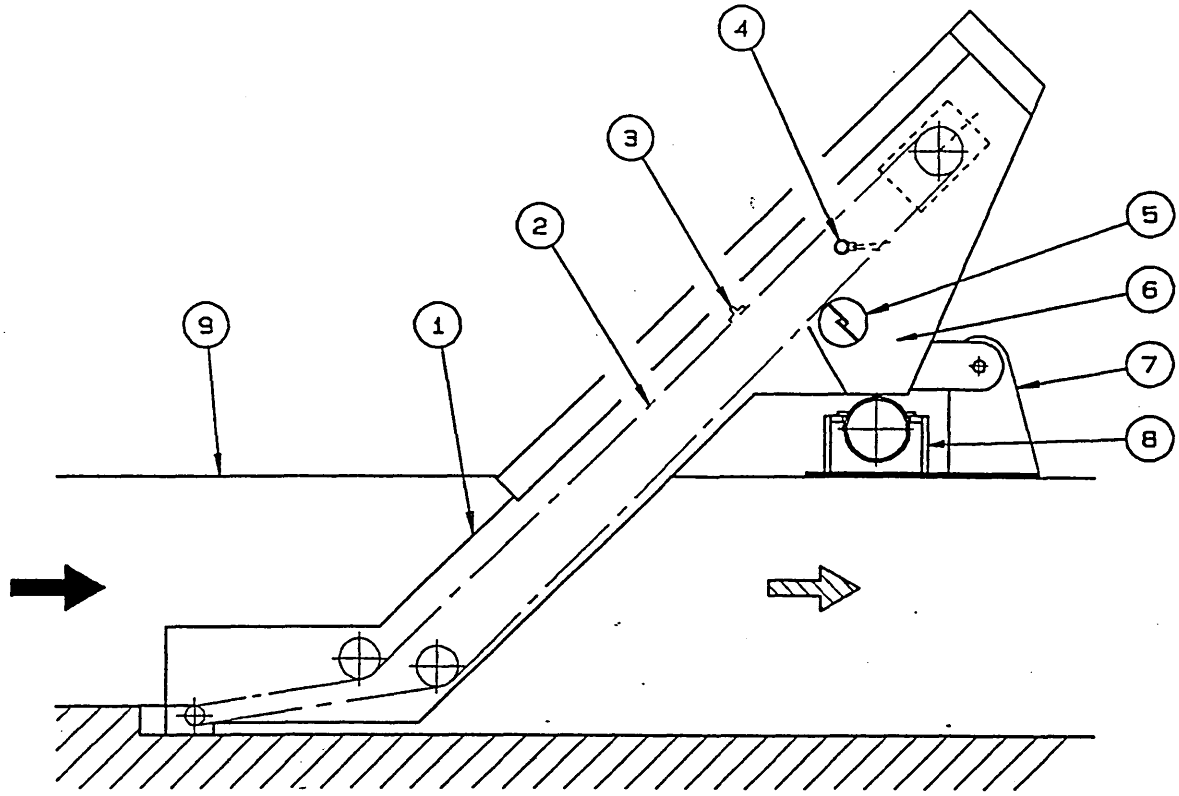


Figure 1.17 Slotted Belt Screen



LEGEND

1. Sideplate
2. Moving plastic belt
3. Belt joint / Solids carrier
4. Belt backwash
5. Rotating brush assembly
6. Discharge chute
7. Pivot assembly (if required)
8. Compactor (if required)
9. Coping level

Figure 1.18 Continuously Moving Plastic Slotted Belt

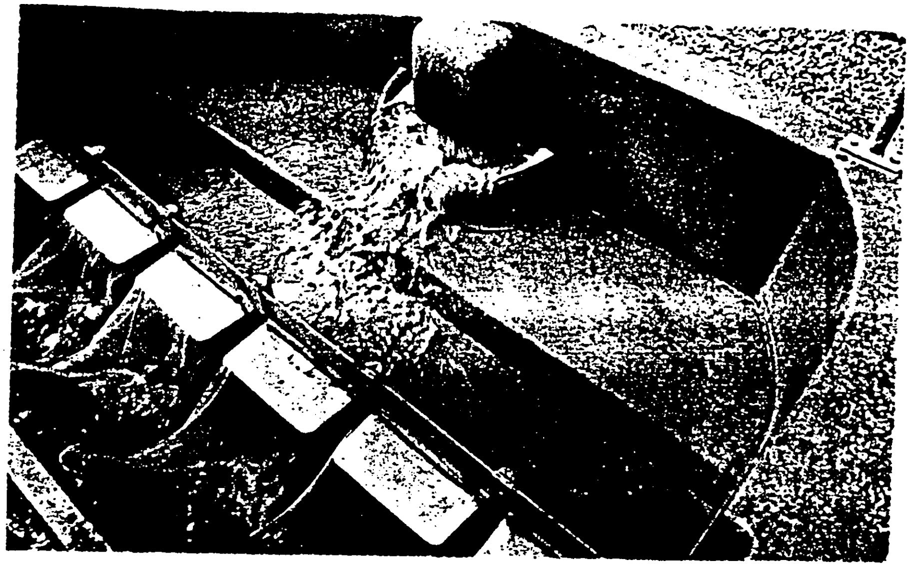


Figure 1.19 Mesh Sacks hung on Overflow Weir

Figure 1.20 Vibrating Mesh Sacks

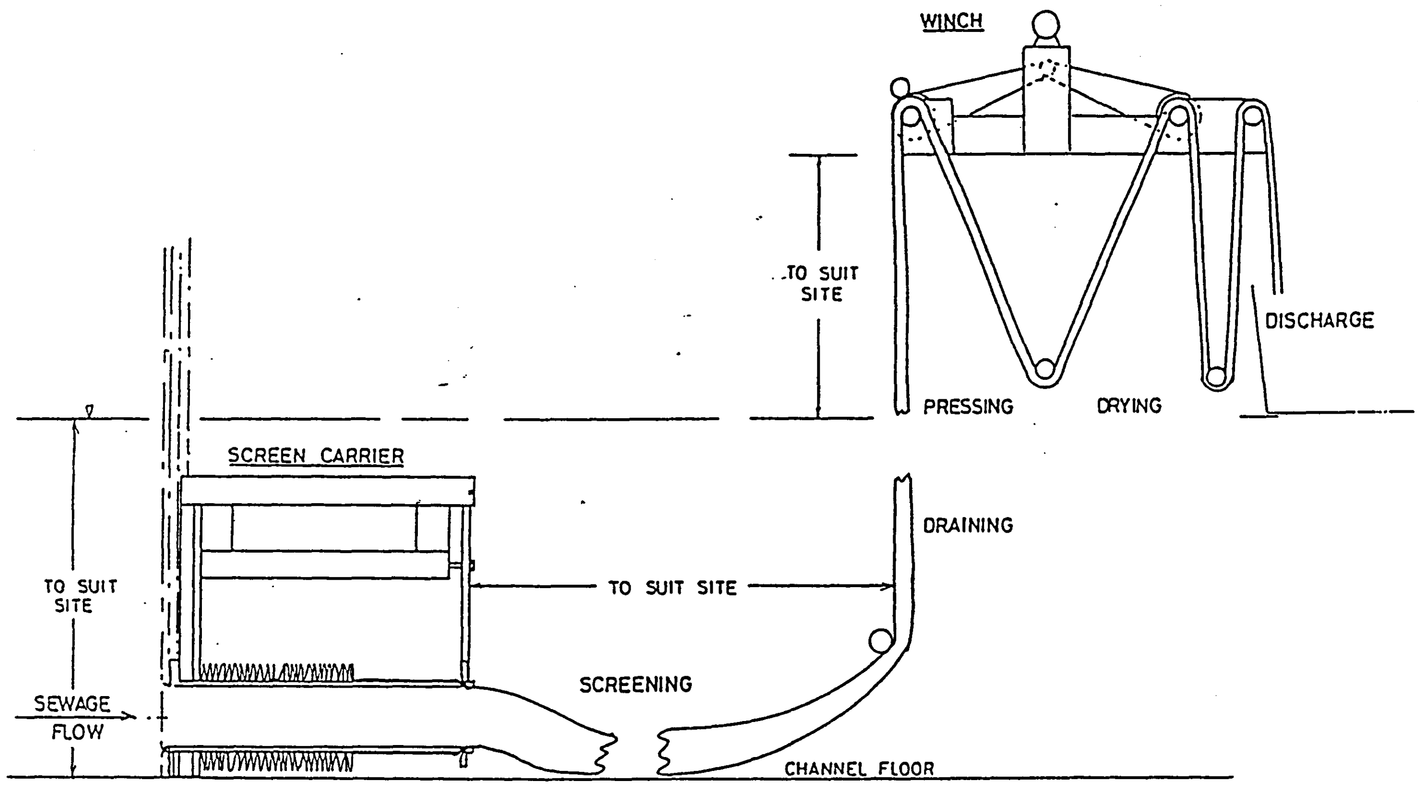


Figure 1.21 Extending Mesh Sacks

sock so a clean area of mesh sack is presented to the flow. Blockage of the spill pipe can occur and the sock must be recovered for disposal after each storm event.

1.7.9 Mechanically Brushed Semi-Circular Perforated Screens

Similar in design to the mechanically raked semi-circular bar screens this screen is manufactured from either semi-circular perforated stainless steel or polyurethane sheet, figure 1.22. The screen is brushed using a rotary four-brush mechanism, the polypropylene brushes remove the gross solids from the upstream side of the screen. The wiping action of the brushes, however, forces some gross solids through the perforations and partial blinding of the screens is common. The screen is weir mounted in the same way as the semi-circular bar screen.

Another perforated screen available consists of a semi-circular perforated stainless steel basket, figure 1.23 Instead of a mechanical brushing mechanism a helically wound screw installed onto the semi-circular screening face transports the gross solids to one end whilst a brush fitted to the leading edge of the flight cleans the screening face. The gross solids can then either be collected or returned into the foul flow. This type of screen can either be positioned horizontally immediately behind the CSO weir or inclined and fitted into the spill pipe. In the latter arrangement the retained gross solids are transported upwards out of the flow via the helical transporting screw and deposited onto a collection hopper. With this screening system, periodic removal and disposal of the collected gross solids is necessary.

1.7.10 Inclined Perforated Belt Screens

Several designs of inclined perforated belt screens exist. The majority consist of rectangular perforated steel or polyurethane panels on frames of stainless steel which are bolted onto drive chains to form a continuous belt, figure 1.24. The panels are cleaned by a combination of rotating brushes and water washing from jets or spray bars which are located at the top of the screens. A more recent design has incorporated steps in the belt by pressing perforated steel panels into shallow

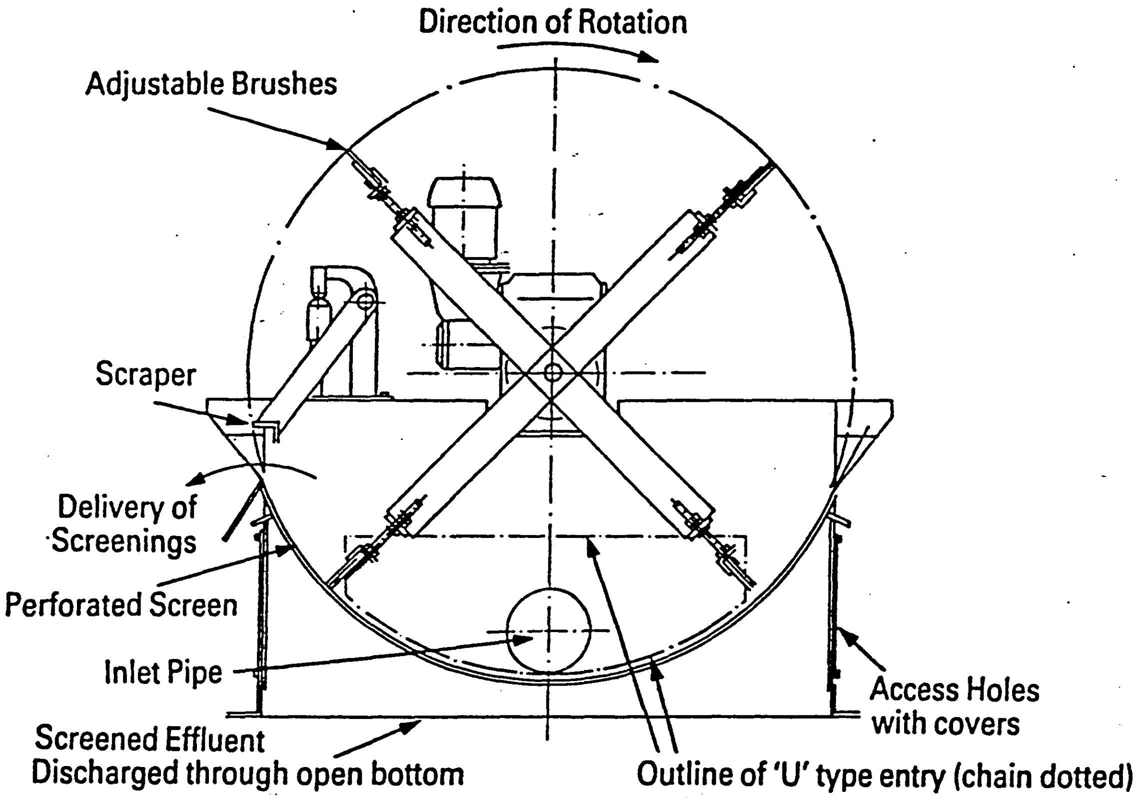


Figure 1.22 Mechanically Brushed Semi-Circular Perforated Screen

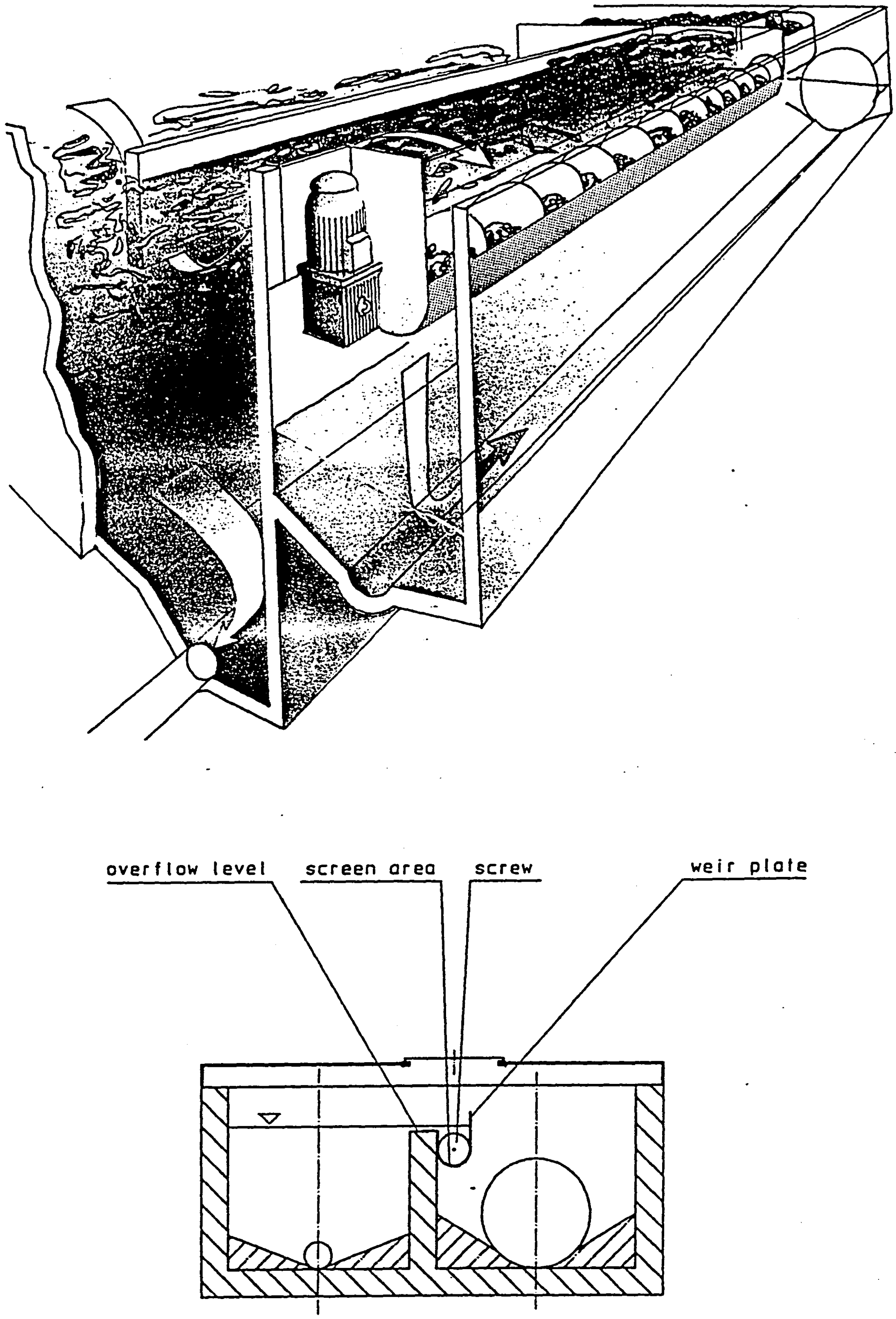


Figure 1.23 Semi-Circular Perforated Stainless Steel Basket

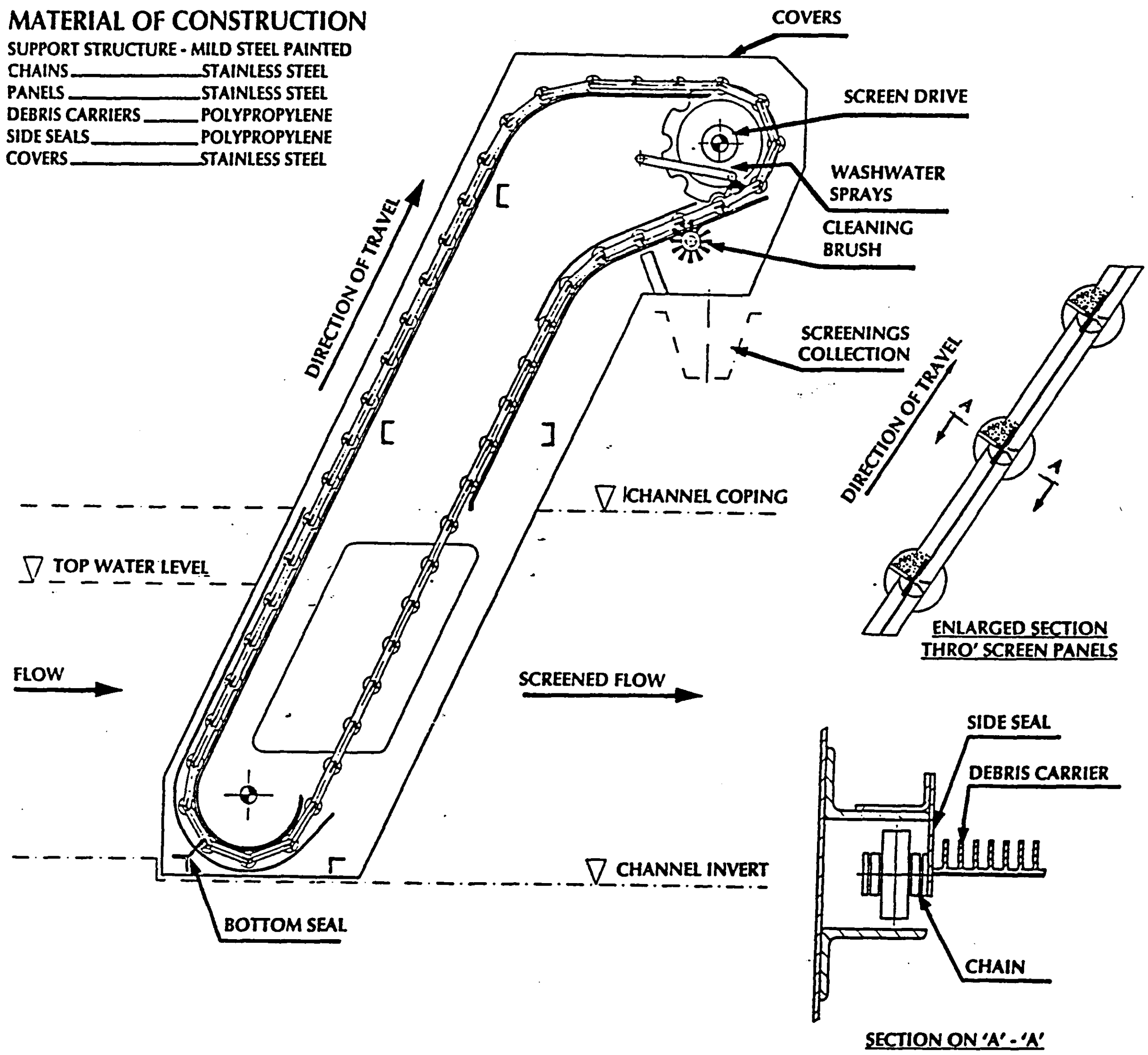


Figure 1.24 Inclined Perforated Belt Screen

triangular prisms and bolting them onto the drive chain so a horizontal ledge at the upper edge of each panel carries the gross solids up the screen face, figure 1.25. To date, this type of screen has not been installed on CSO's

1.7.11 Rotating Drum Perforated Screens

Rotating drum or cup screen cylinders operate in the same manner as the rotating drum bar screens. They comprise a steel framework with the screen face built up from curved perforated steel or polyurethane panels, figure 1.26. Removal of the gross solids is usually carried out with a combination of rotating brushes and backwashing from water jets or spray bars positioned above the drum. The gross solids then fall back into the foul flow or into a collection hopper located inside the drum above the flow level. A water powered rotating drum screen is also available.

1.7.12 Disc Screens

A recent design to enter the market is the disc screen. The screen is made up of a number of vertical shafts each fitted with overlapping and intermeshing discs with an aperture distance to suit the fineness of screening required, figure 1.27. Each shaft rotates slightly faster than its upstream neighbour thereby forming a gentle conveying action of gross solids across the face of the screen to the discharge point. The gross solids are either discharged from the screen back to the foul flow or removed from the flow by means of a submersible pump, rundown screen and compactor. The disc screen is mounted on the CSO weir.

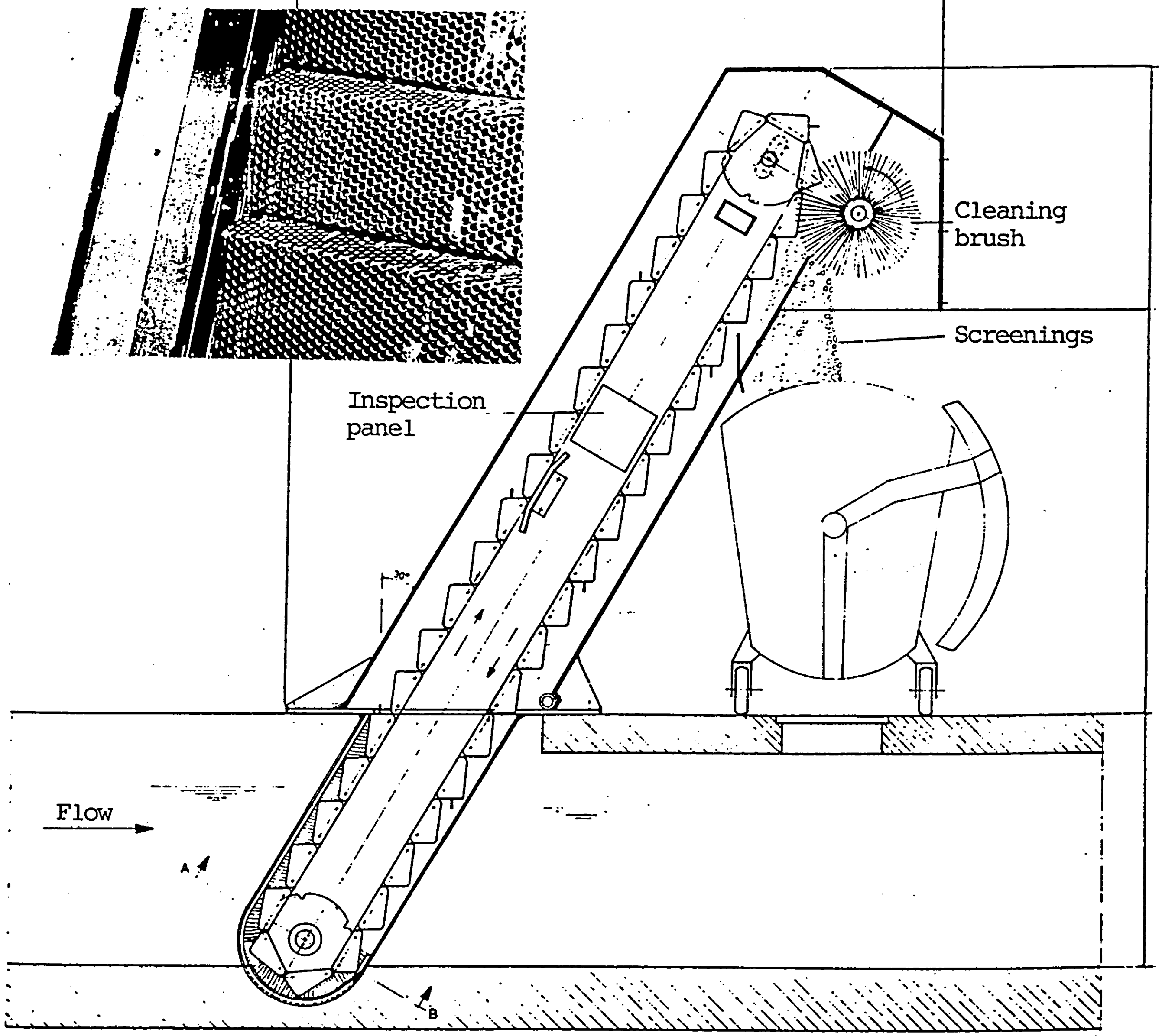
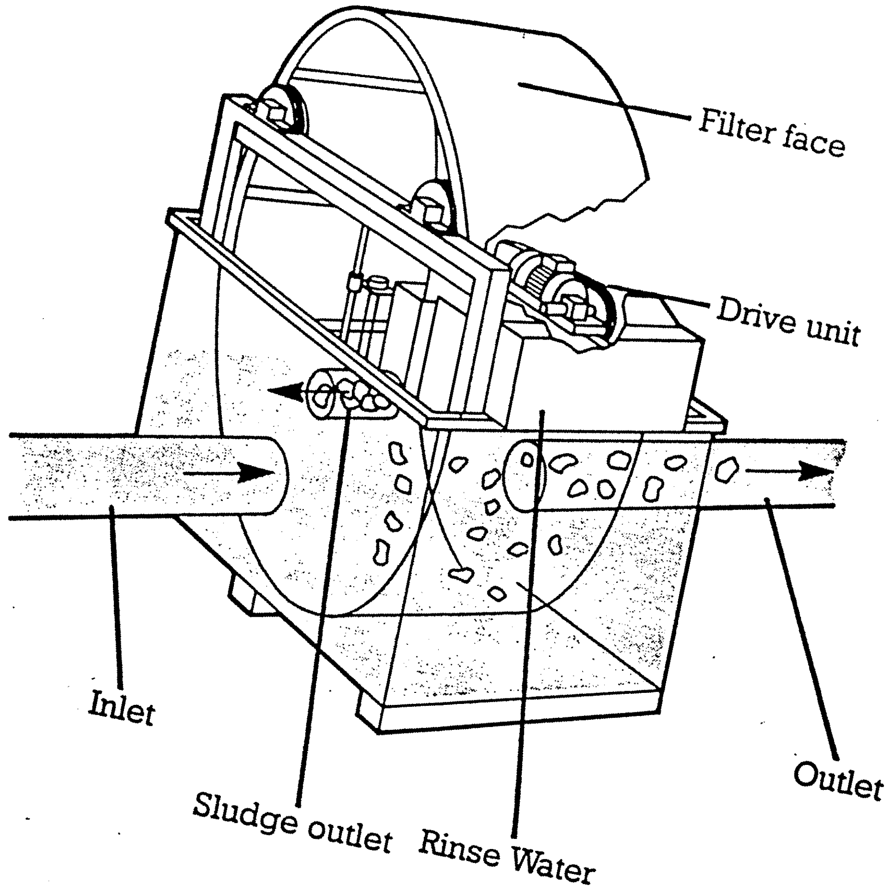


Figure 1.25 Inclined Stepped Perforated Belt Screen



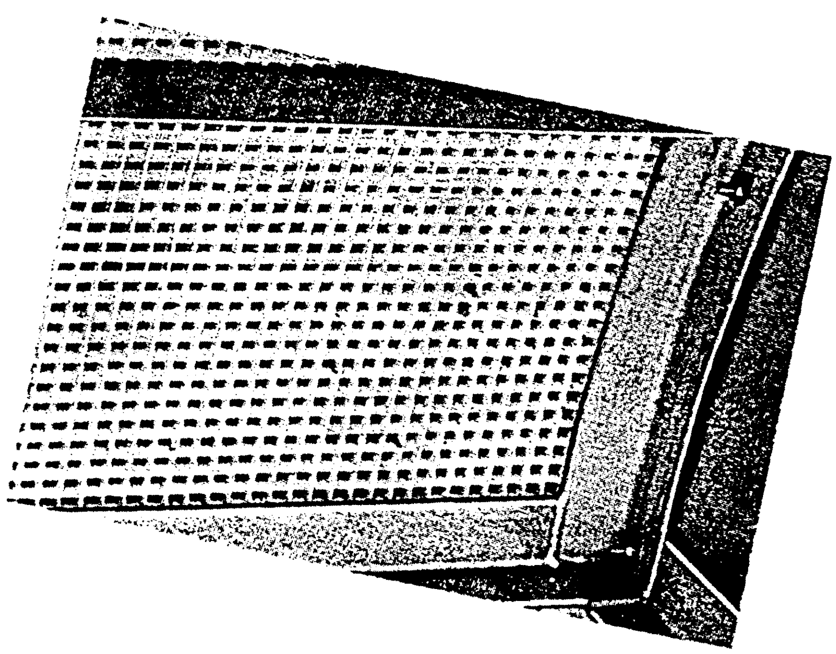


Figure 1.26 Rotating Drum Perforated Screen

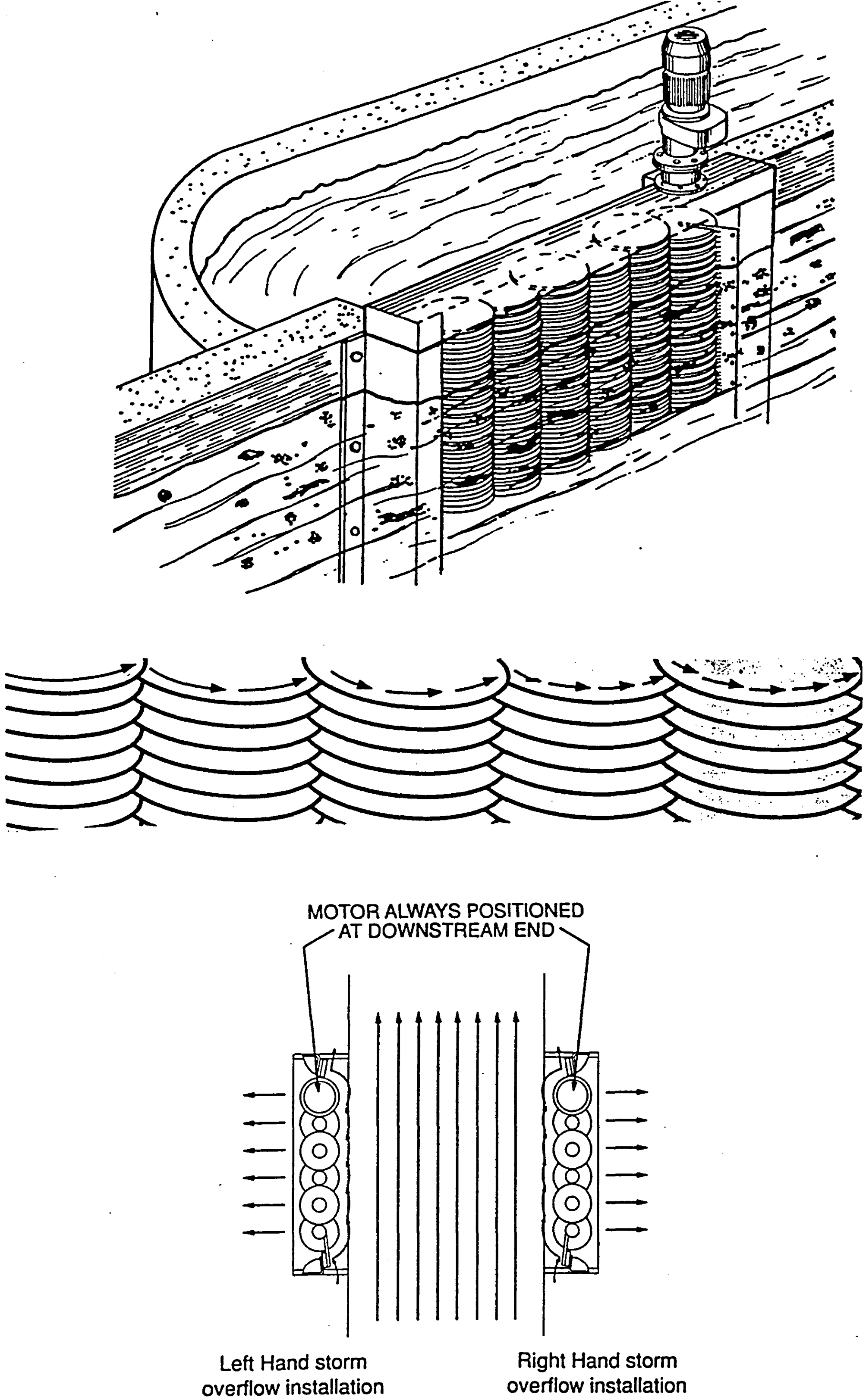


Figure 1.27 Disc Screen

1.8 Project Objectives

Much has been said about the potential of screens for retaining aesthetic pollutants within the sewerage system and preventing them spilling to watercourses. However, little field work has been done to establish their true performance. If screens are to become an established part of future procedures for preventing aesthetic pollutants being discharged to watercourses and perhaps becoming conditions of consent for individual combined sewer overflow structures it is important that their performance be fully investigated. Further work was therefore required to determine screen performance.

The objectives of the project were

- To determine the performance and efficiency of different types of CSO Screens
- To identify the factors which influence screen performance
- To assess the hydraulic performance of the CSO's
- To identify the sources and type of gross polluting solids

CHAPTER 2 REVIEW OF PREVIOUS WORK

2.1 Previous Work on Screen Performance

2.1.1 Sidwick J M, 1984 & 1985

One of the overall objectives of the project was to examine in detail the various methods available for screenings and grit removal, separation, treatment and disposal and ascertain their effectiveness. The following definition were used:

Fine Screen	A screen with spacings between bars or diameter of perforations between 3 and 15 mm
Medium Screen	A screen with spacings between bars or diameter of perforations between 15 and 50 mm
Coarse Screen	A screen with spacings between bars or diameter of perforations >50 mm
Milliscreen	A screen with spacings between bars or diameter of perforations between 0.25 and 3 mm
D-Screen	A screen with a semi-cylindrical cross-section
Grab Screen	A continuously-raked straight bar screen, normally inclined at 75° to the horizontal, usually installed at depth, bar spacings between 12 & 18 mm
Continuous-chain Screen	A screen fitted with a continuous-chain, multi-rake mechanism, bar spacings between 12 & 18 mm

The preliminary report concentrated on the removal, treatment and disposal of screenings and grit in sewage at treatment works and sea outfalls. The information collected represented a summary of the views of the UK water industry. This summary was an objective interpretation based on over 300 completed questionnaires and the views expressed by representatives of water authorities and manufacturers during meetings. During phase 1 of the project it was established that medium bar screens were inefficient and probably only removed < 50% of gross solids. The report found that many downstream problems at sewage treatment works were caused by the inefficiency of screens and disintegrators and concluded that more needed to be known about certain aspects of gross solids removal from sewage and their subsequent treatment and disposal. The report recommended that:

- consideration be given to the development of back-raked versions of the currently available front-raked screens;
- that all rakes should be capable of two-speed operation, the higher speed to be used at times of maximum load;
- that a device be developed for sensing an impending storm flow and then initiate continuous screen raking at the highest speed prior to the first storm flush reaching the screen.
- that techniques be developed whereby the efficiencies of gross solids removal units could be measured.
- that attempts be made to persuade manufacturers of relevant plastic artefacts that were often discharged to the sewer to change to using biodegradable materials.

An indication of the nature of gross solids was given by inspecting three sewage treatment works; table 2.1:

Table 2.1 Nature of Gross Solids at Three STWs

Visual analysis of gross solids from screens (by volume, %)	Works A	Works B	Works C
Rags	70	64	15
Paper	25	25	50
Rubber	-	-	5
Plastic	5	5	20
Vegetable Matter	-	1	5
Faecal Matter	-	5	5

Considerable variation in the character of the gross solids was found among the three works

Phase 2 of the project investigated the consequential costs associated with the downstream problems resulting from inadequate screening on attended works. In addition to this, one of the objectives of phase 2 was to establish whether or not any attempt had been made to quantify the volume of screenings in sewage for the purpose of determining screen/disintegrator efficiency. Standard letters were sent to contacts both in the UK and overseas, these included water authorities, research laboratories, pollution control authorities, government ministries and departments, universities, consultants and manufacturers, 499 letters were dispatched to contacts in 47 countries. By the end of August 1985 replies had been received from 29 countries and nearly all the replies were negative. Where efficiency of screens or disintegrators had been examined tests using cage screens suspended in the sewage flow had been used or in-flow or side-stream fine screens were used. From the widely circulated enquiry it was concluded that no attempt had been made worldwide to develop a valid test for measuring screen and disintegrator efficiency

2.1.2 Anderson J A and Bahmani M J, 1985

The paper describes experimental tests to determine the hydraulic characteristics of a perforated plate when partially covered with solid material.

Theory

Flow and Pressure Drop Characteristics for Orifices with Square Edges

It was assumed that orifices are regularly spaced over the area of the constriction so that flow through any one orifice may be considered typical of the flow in all the other orifices. The pressure drop (Δp) across the plate can be specified in terms of a dimensionless pressure coefficient k.

$$k = \frac{\Delta p}{\frac{1}{2}\rho V^2} \qquad (2.1)$$

Where V = approach velocity in the duct/channel

Dimensional analysis shows that for an incompressible fluid

$$k = \Phi \text{ (Re, Screen geometry)} \qquad (2.2)$$

Where Re = Reynolds number based on hole diameter and the mean velocity in the holes

Ignoring the upstream velocity head, the flow through a perforated plate can be written as:

$$Q = C_d A_f \sqrt{2gH_o} \qquad (2.3)$$

Where A_f = the total area of openings in the plate

Q = flowrate

H_o = reduction in water level on passing through the plate

Ignoring the change in velocity level upstream and downstream of the plate, the head loss on passing through the plate equals Ho and the pressure loss Δp is given by

$$\Delta p = \rho g H_o \qquad (2.4)$$

Equation (3) can be written as

$$Q = C_d \alpha A \sqrt{2gH_o} \qquad (2.5)$$

Where A = upstream cross-sectional area of flow.

Using equations (2.1), (2.4) & (2.5) gives:

$$C_d = \frac{1}{\alpha k^{\frac{1}{2}}} \qquad (2.6)$$

Where α = porosity of the plate $\left(\frac{A_f}{A}\right)$

Experimentation

A 6 mm thick perspex plate with eighteen 6 mm diameter holes was fixed normal to the flow in a vertical 51 mm diameter pipe. Pressure tappings 75 mm upstream and 75 mm downstream of the plate were used to measure the pressure loss for a range of flowrates. Initially the tests were carried out with clean water, small pieces of cotton wool were added later to simulate the effect of solids loading on the plate. The cotton wool pieces were weighed dry before each test, they were then added to the flow through an overflow valve above the perforated plate being of sufficient size to be retained on the plate. The plate was removed at the end of each test to check the cotton wool had not passed through the holes. The thickness/diameter (t/d) ratio for the plate was equal to unity and the porosity (α) equal to 0.251.

The clean water head loss H_o from the experimental tests when plotted against the square of the flowrate Q_o^2 was found to give a straight line through the origin with C_d = 0.944 and k = 17.6. For the solids tests the head loss H plotted against Q^2 for a constant dry mass (0.09 grams) of solids retained on the plate showed that H was proportional to Q^2. The effect of solids loading on the head loss across a perforated plate was evaluated for cotton wool pieces and found to conform to the empirical equation

$$\frac{H}{H_o} = \left(\frac{Q}{Q_o}\right)^2 e^{k_1 M} \qquad (2.7)$$

Where M = dry mass of solids retained on the perforated plate in grams

k_1 = 5.5 for cotton wool

The head loss H was found to increase exponentially with the dry mass of solids and the value of k_1 varied depending on the characteristics of the wet solids on the perforated plate.

2.1.3 Cookman I J R, 1986

The paper outlined the historical developments of inlet works screening machinery and compared the operational efficiency of the traditional bar screen with that of alternative screening methods available. The author concluded that:

- The problems experienced at sewage treatment inlet works from synthetic fibre fabrics and disposable items of clothing needed to be solved by the provision of more efficient screening equipment.

- There was a need to provide a finely perforated screen capable of handling a wide range of sewage flow without the particle size of gross solids passing through the perforations changing.
- The head loss through perforated screens became a problem as the quantity of gross solids increased significantly at higher flow rates.
- Simplicity and robustness with the minimum of wearing components were essential elements in the design of inlet works screens.

Two tests were carried out at an inlet works on a bar screen with semi-rotary reciprocating rake. The screen had a 19 mm clear bar spacing with 65 mm deep x 15 mm tapering to 10 mm wide bars. A 12 mm square mesh was inserted downstream of the screen for a 30 minute duration, the flow rate during the test was measured as being 160 l/s. After the test the wet weight of gross solids captured by the mesh was found to be 5.5 kg and the wet weight of gross solids captured by the screen 9.5 kg. For the second test a 25 mm A/F hexagonal mesh was inserted downstream of the screen for a duration of 9 minutes. The wet weight of gross solids captured by the mesh was measured as 5.5 kg and the wet weight of gross solids captured by the screen 6.1 kg.

The author concluded that no acceptable solution to the problem of low capture efficiency of the bar screen had yet emerged. However, the trials carried out on the bar screen were not carried out on the alternative methods of screening described so no real comparison between the different types of screen equipment available could be made and the two tests performed did not provide conclusive results as to the ineffectiveness or otherwise of the bar installation.

However, the historical review did show that there were no new concepts in screening and that the further developments that had been made had only increased screen reliability.

2.1.4 Page S J, 1986

The objectives of the work were to determine:

(i) the screenings loads in the flow at the existing Ray Hall sewage treatment works;

(ii) the most appropriate type of screen for a new inlet works to be built at Ray Hall;

(iii) the scale of screenings-related problems downstream of the works following construction.

To complete the work an assessment of the quantities of screenings occurring at Ray Hall was necessary. Two evaluation methods were used, the first utilised existing data on the volume of screenings collected and disposed of at the works which gave a long term mean quantity. Instantaneous rates of inlet screen screenings capture were also recorded by equipping the screenings collection skip with a weighing platform and data logging equipment, set to log at 15 minute intervals. The second method involved using hand-held fine mesh screens for determining the efficiency of different types of inlet screen and for sampling works flows. Previous tests had indicated that mesh screens with apertures < 12.5 mm retained excessive amounts of hair and small pieces of tissue, these screenings were considered insignificant in terms of associated downstream problems. Several tests were carried out in which the whole of the flow was screened using a 12.5 mm square mesh directly followed by an 8 mm square mesh. These tests assessed the screenings composition and established the mass of screenings passing the 12.5 mm mesh screen. It was found that the 8 mm mesh caught approximately 30% (by weight) more screenings than the 12.5 mm mesh. Any screenings passing the 8 mm mesh were considered negligible since all of the screenings retained by this screen were small pieces of tissue. This established that the 12.5 mm mesh screen was retaining all of the screenings which caused significant downstream problems.

Initial tests involved screening the whole of the flow leaving the detritor, to provide a measure of the screenings load passing the inlet screens. A 2 m x 1 m square mesh, 12.5 mm aperture screen was inserted into the channel for 30 seconds, the time period chosen to prevent any errors from screen blinding. The test method was found to be cumbersome and was abandoned in favour of sampling portions of the flow along the length of the detritor inlet with a 0.7 m x 1 m square mesh, 12.5 mm aperture screen using sampling times of 30 seconds to 10 minutes. Both methods tried were found to give essentially the same value of screenings loading. Similar methods were used to sample the sludge from the primary sedimentation tanks and the settled sewage at the works.

Several other inlet works screenings loadings were assessed using a similar sampling method to that described. A 0.3 m x 0.3 m square mesh, 12.5 mm aperture screen was used, the mesh being made up of two 12.5 mm bar screens capable of being separated after each test for ease of cleaning. Samples were taken such that the whole of the flow area was covered e.g. for a 1 m wide channel with 0.7 m deep flow six sample were taken, using a 30 second to 2 minute sampling period. During development of the testing method a number of samples from the crude sewage, sludge and settled sewage were sent for dry weight analysis and the percentage of dry matter was found consistently to be approximately 15%.

The screenings capture efficiency (E) of curved bar screens was also assessed using the following definition:-

$$E = \frac{\text{(Upstream load - Downstream load)}}{\text{Upstream load}} \times 100\ \% \qquad (2.8)$$

Similar test methods were used to assess the screenings loading upstream and downstream. Sampling was alternated between the flow upstream of the screen and the flow downstream of the screen using a 0.1 m x 0.1 m square mesh, 12.5 mm aperture screen. By alternating the sampling any variation over the whole sampling period was accounted for. Curved bar screens ranging from 12 mm to 100 mm were examined and efficiencies were found to vary from 71% to 42%.

It was concluded that

- a relationship between screen bar spacing and screenings capture efficiency seemed to exist but more data were required to establish this;
- Assuming a relationship between bar spacing and capture efficiency the majority of inlet works mechanical screens were only 50% to 60% efficient for 12.5 mm solids and above;
- The capture efficiency had fairly broad limits for different types of sewage and rates of flow;
- Of the total screenings load incident at a works, 99.8% is removed by primary treatment, i.e. screening and primary sedimentation. All downstream screenings related problems were caused by the remaining 0.2% implying that little, if any, reduction of these problems would occur if inlet screen efficiency increased.
- Further trials should be performed with various mesh sizes to further test the validity of the results.

These methods of evaluating screen capture efficiencies appear to work well for inlet works screens, however, the screenings considered to be a negligible problem downstream of the screens at a sewage treatment works cause considerable aesthetic pollution when discharged into a watercourse from a CSO and should, therefore, be evaluated in a testing methodology.

2.1.5 Hopkins P D and Marshall R J, March 1986

Financial and environmental arguments for and against the use of CSO screens were discussed together with the differing approaches of two water authorities and their agents. It was concluded that if it is deemed necessary to install a screen in a CSO to reduce the aesthetic damage to the receiving watercourse then a satisfactory solution may be found. While the cost of installing screens on CSO's was generally small in comparison with the cost of the sewer system, the running costs of a screening installation could be substantial, the largest part of the running cost being associated with maintenance. It was concluded that the cost/benefit aspect would have to be looked into very closely before installing screens and it would be better, therefore, to achieve the same objective by hydraulic means without resorting to screening.

North West Water

North West Water's Sewerage Manual stated that if the receiving watercourse is of a significant amenity value then consideration should be given to the provision of automatically raked screens. However, screens should only be installed if the location of the overflow is such that there is a readily available power supply and there is good access for ease of future maintenance.

North West Water had no record of the number of screened CSO's in its region. Opinion on CSO screening was divided, certain agent councils were known to have satisfactory screen installations, others thought they were "more trouble than they were worth". A survey carried out in 1984 found there were thirty mechanically raked screened CSO's within the region. Of these, a subjective judgement found that 16 were apparently effective, 8 were probably effective and 6 were either poor, abandoned or detrimental.

The study group visited 4 installations which had been indicated as satisfactory from both river water quality and operational standpoints. Two were mechanically raked semi-circular bar screens mounted on CSO side weirs, the other two were vertically raked bar screens installed on the spill channel downstream of the CSO weir. Evidence of rags etc. was found at the discharge points of all 4 installations. It was not clear whether this was due to normal screen operation or the by-passing of the screens on occasion. The study group found that there was insufficient evidence to point to the advantages or otherwise of the differing screen bar spacings or dimensions. The group also carried out a literature survey to find information on the performance of such installations but failed to reveal anything useful. The study group completed a similar exercise to establish the effectiveness of unscreened

CSO's and concluded that it was possible to design an overflow which retained sufficient solids without screening. However, the monitoring of performance between the screened and unscreened CSO sites was not fully comprehensive. The study group found that there was no fundamental reason why automatic mechanically raked screens on CSO discharges should not be considered for particular applications.

Yorkshire Water Authority

It was Yorkshire Water Authority's practice that all new discharges of storm sewage should be screened, the screens being mechanically raked where practicable and the design of the chamber being such as to provide an automatic means of returning the gross solids to the flow passed forward for treatment. Seventeen mechanically raked screens had been commissioned in Sheffield, all were radially raked mechanically operated, automatically controlled bar screens either installed on the crest of the weirs of either side weir CSO's or stilling pond CSO's. The following method of estimating screen size was used in Sheffield:-

- An appropriate spacing between bars was chosen, 10 mm was considered to be a minimum.
- The average velocity through the screen, V, was estimated and should be in the region of 0.75 m/s to 1.0 m/s.
- The total area of screen immersed was then found using the following expression:

$$\text{Total area of screen immersed} = \frac{Q \times (S + B)}{\left(\frac{S}{V}\right)} \qquad (2.9)$$

S = Bar Spacing (Minimum 10 mm)

B = Bar Width

V = Average Velocity through Screen (m/s)

Q = Design Flow (cumecs)

- The remaining screen dimensions, e.g. rake radius and screen width, were established using the required area, the available headroom, the maximum width for an individual screen unit and any requirements specific to the CSO.

No model testing or quantitative prototype monitoring was carried out in Sheffield but regular visual inspections suggested that the method arrived at appropriately sized screens.

2.1.6 Hubbard A M and Crabtree H E, 1986

The work of Page S J, 1986 established two tests for monitoring screen performance and these were used to evaluate Minworth STW inlet works gross solids removal efficiency. The inlet screens at the works consisted of a 100 mm bar screen followed by a 37 mm bar screen. The gross solids load in crude sewage was established by sampling the incoming flow. Fifteen readings were taken over a whole afternoon by immersing a 0.1 m^2 screen of 12 mm mesh into the flow for 30 seconds and weighing the accumulated gross solids. This total mass of gross solids accumulated was then translated into a total gross solids load per minute over the whole channel (the cross-sectional area of incoming flow being approximately 7 m^2). The percentage of dry matter measured by Page S J, 1986 was used to establish a dry gross solids load entering the works per minute. The mass of gross solids removed by the inlet works were found by weighing the pressed gross solids cakes produced in 130 minutes from four rag presses. From this a total mass of dry gross solids removed from the flow and pressed per minute was found. The inlet works gross solids removal efficiency was defined as

$$\frac{\text{Mass dry matter pressed per minute}}{\text{Mass dry matter in crude sewage}} \qquad (2.10)$$

The gross solids removal efficiency was found to be 43%. It was found, however, that not all of the gross solids removed by the screens were retained in the rag presses, a large proportion of the screened and laundered material was in fact returned to the flow and the actual screen efficiency was estimated to be nearer 55%.

The report concluded that test procedures were available for monitoring screen performance but the results for curved bar screens (Page S J, 1986) did not indicate a clear cut relationship between bar spacing and efficiency. Other variables (eg. velocity, bar shape) would affect performance and could only be studied under standard conditions.

2.1.7 Sidwick J M, 1988

This CIRIA technical note reported on the third phase of a CIRIA research project which dealt with the removal, treatment and disposal of screenings and grit in sewage. Phase 3 of the research project concentrated on the problems experienced upstream of the sewage treatment works inlet and more specifically to the problems experienced at, or caused by, CSO's and in-sewer pumping stations. The definitions in the previous report (Sidwick, 1984) were used. Twelve CSO's and pumping stations were visited, a number of desk studies and literature searches were carried out and meetings held with knowledgeable people in the water industry. It was clear from discussions and relevant literature that gross solids entering the watercourse from CSO's caused aesthetic pollution especially when caught on vegetation and gabions, and this was considered objectionable by the public. It was found, however, that diametrically opposed views were held by water authorities and local authorities with regard to CSO screening policy. One regional water authority always installed screens on CSO's where there was a power supply, another only installed screens if they were considered to be absolutely essential.

Screens were found to be commonly installed at CSO's but there was a trend towards reducing the frequency of CSO screen installation. The commonest screening system used was the D-screen with 12 to 18 mm bar spacings positioned on the overflow weir, the gross solids being raked back into the foul flow. It was found that D-screens can operate satisfactorily but when installed on side weir overflows difficulties could arise from poor chamber design. If the chamber became hydraulically overloaded then the upflow rate could be such that the screenings were returned to the screen immediately after being removed from it and blockage of the screen in this situation was common. This resulted in the discharge of unscreened storm sewage into the watercourse and impairment of the hydraulic characteristics of the weir.

Grab screens and continuous-chain screens were also used on CSO's and were normally located in the spill channel. Other types of medium screen were also found in use on CSO's. It was concluded, that, in principle, any type of sewage treatment works screen could be utilised on CSO's. However, fine screens were hardly ever installed on CSO's.

The research project found that bar screens with spacings between the bars of 12-18 mm were inefficient, although the actual screen efficiency could not be quantified in terms of screenings capture. These bar screens did, however, intercept a proportion of gross solids and therefore reduced aesthetic pollution to some degree.

The installation of medium bar screen on CSO's was not recommended except in situations of marginal environmental sensitivity. Only in situations of extreme environmental sensitivity, was the fine screening of CSO's recommended.

The report concluded that the installation of screens on CSO's could not be justified on grounds of economy alone but that screening may well be justified environmentally even when cost effectiveness could not be demonstrated.

2.1.8 Yeh H H and Strestha M, October 1989

The primary objectives of the study were to understand the flow through a screen in an open channel and to provide a prediction model for the headloss associated with a screen inclined at various degrees to the vertical. A theoretical model was produced and laboratory tests were carried out in order to validate the model.

Experiments were performed in a 7.32 m long x 0.31 m wide x 0.52 m deep horizontal flume. A Johnson wedgewire screen was used for the tests which consisted of stainless steel wires 1.91 mm wide, spaced 3.75 mm centre to centre with transverse support bars spaced 38.1 mm between centres. A single horizontal rod held the screen in position in the channel. The depth of flow upstream and downstream of the screen was measured using a pointer gauge. The head loss was then calculated using:

$$\frac{q^2}{2gh_1^2} + h_1 = \frac{q^2}{2gh_2^2} + h_2 + k\frac{q^2}{2gh_1^2} \qquad (2.11)$$

Where q = flow rate per unit width of the channel

h_1 = upstream flow depth

h_2 = downstream flow depth

k = headloss coefficient

A flow visualisation technique was used to observe the flow patterns through the screen. Polystyrene particles were uniformly introduced into the header tank, a thin sheet of light was projected in a vertical plane parallel to the flow direction, illuminating the particles in the test section. The particle motion was photographed using a long exposure time so the particles appeared as streaks in the photograph. The technique showed that the water surface decreased immediately behind the screen due to the fluid acceleration by contraction of the flow. So, even though the flow approached perpendicular to the screen, the streamlines were deflected downward near the free surface. Flow separation occurred along the bottom boundary when the screen was vertical, the separation was found to be suppressed when the screen was inclined due to flow deflection caused by the approaching flow no longer being perpendicular to the screen

The paper concluded that the head loss for the vertical screen was somewhat higher than the predicted value, this was explained by the separation of the flow along the bottom boundary behind the screen. The theoretical model predicted that to minimise the head loss there was an optimal screen inclination of 80° to the vertical, however, the minimum head loss was found to occur with less inclination than the predicted at 60° to the vertical and the headloss at the optimal screen angle was greater than the predicted value.

2.1.9 Thomas D K, Brown S J and Harrington D W, December 1989

Investigations were undertaken into the performance of screening equipment at marine outfall headworks as part of a collaborative programme between Welsh Water and WRc. Only limited studies had been previously undertaken to measure the performance of screening equipment at outfall headworks or sewage treatment works sites and no single test had been developed for measuring performance under a wide range of conditions or site configurations. A range of tests were developed to provide information on the efficiency of capture of gross solids by different screens, and the changes brought about in gross solids loadings and size fractions by the screening process. The methods of performance measurement were applied to 13 different screen types at 21 different locations throughout England and Wales. The object of the research was to provide information for staff involved in the design and operation of marine discharges to assist in the correct choice of screening equipment to meet environmental and emission standards. Screen performance was evaluated using plastic tracer materials, such as, condoms, backing strips from sanitary products and cotton buds, which were dosed into the sewage flow upstream of the screen, the numbers retained and passed being noted. By using a range of products with differing dimensions the performance of the screen in relation to its nominal aperture size was established. Performance curves of tracer material capture rates for a range of dimensions were plotted, a comparative measure of capture efficiency was also produced by plotting the capture rate percentage of all the screens against the screen size. This demonstrated that the area of the screen aperture was critical to capture efficiency, the greater the area, the lower the efficiency. These figures demonstrated that correct terminology was critical when defining screen aperture size, e.g. a 6 mm bar aperture screen had a greater area than a 6 mm circular aperture perforated screen and as such should not have been described as a 6 mm screen.

The gross solids load and size distribution in the sewage flow before and after screening was measured using an aluminium framework into which three wire mesh grids were installed so that the sewage passed through 17 mm, 12 mm and 6 mm meshes, arranged in series with a 25 mm spacing between them. The test involved in-situ removal of gross solids from the sewage, separation into size fractions and measurement of sample flows to estimate loadings. The change in proportions of gross solids (dry weight per volume of sewage) collected on each mesh following screening gave a measure of screen removal efficiency. Two other tests using first a hydrodynamic separator and then a run-down screen were also used to evaluate gross solids loading.

From the screen types tested, milliscreens such as the Contrashear (0.5 and 1.0 mm) and Rotostrainer (2.5 mm) and fine screens such as the Longwood 'D' Screen (3 and 6 mm) and Brackett Cup Screen (5 mm with modified contact seals) appeared capable of achieving the required standards (for long sea outfalls - a 6 mm maximum particle size), if correctly installed, operated and maintained. Improved performance could have been achieved by better contact seals or a change in operational procedures. The report pointed out that the installation of finer screens may lead to large quantities of faecal solids content, and provision for washing and dewatering in the screenings handling process was seen as important.

It was recognised that screening of storm water discharges required careful attention as these discharges could devalue improvements brought about by more efficient screening of dry weather flows. Screening, for the most frequent storm flows, should be carried out to remove 6 mm, and above, particle size. Screenings from storm flows in excess of this should be removed by the best available technical means not entailing excessive cost for later return to the flow. As it may not be feasible to provide fine screening to all storm flows, it was therefore inevitable that some identifiable persistent debris would reach the marine environment under extreme storm conditions. It was seen as important to continue efforts to encourage the use of readily biodegradable materials, and in the absence of voluntary measures, consideration should be given to promoting legislative controls and greater public awareness of the need for alternative disposal routes for non-biodegradables.

The need for more precise aperture size definitions when describing screens was emphasised, as the testing had clearly demonstrated that any screen aperture exceeding 6 mm in any dimension could not achieve a 6 mm particle size emission standard.

The method used for measuring screen performance did not account for the dispersed fibrous and tissue paper which forms a considerable proportion of the gross solids arriving at and passing through screens. Tracer materials added to the flow are not representative of the gross solids in sewage, clean products have not experienced the amount of degradation that the gross solids already in the system have. Additionally, the method of insertion of the tracer materials into the flow upstream of the screens may influence the way in which they are presented to the screen and therefore the efficiency of retention of the material by the screen.

2.1.10 Thompson B, Webster S and Renvoize T, March 1993

A series of trials were carried out at Portrack STW to evaluate inlet works screens, originally to help in the selection of screening equipment for a sea outfall/headworks project. Four screening machines were installed parallel to each other at Portrack STW such that each machine screened one quarter of the flow entering the works. The four machines were a Vickerys Aquaguard, a Brackett Green Finescreen, a

Bormet Finescreen and a FSM Finescreen. It was felt that these four machines represented the European market leaders in their field at these large sizes. The trials were carried out for a 12 month period, after the first 6 months, Vickerys replaced the Aquaguard with their latest machine the Vickerys Aquascreen. The tests and assessments carried out on the machines were as follows:-

- Gross solids collection - Gross solids removed by each machine were collected simultaneously over a set time period by inserting a tray into the discharge hopper of each machine. The gross solids were weighed, photographed and their content visually assessed.
- Flow sampling - Samples were taken by inserting Copasacs (plastic mesh sacks) upstream and downstream of each screen simultaneously over a set time period. The Copasacs were weighed wet, allowed to dry for seven days then weighed again and their contents assessed visually. The upstream Copasacs were compared to assess the distribution of gross solids loading per machine.

  Any gross solids passing through the screens were caught by 6 mm diameter perforated stainless steel plates inserted simultaneously downstream of each screen, alternatively 25 mm and 50 mm mesh nets were inserted in the same manner.
- Mechanical assessments - Each screen manufacturer sent a representative to site on the Wednesday of their allocated "maintenance week" who, under inspection, carried out mechanical checks on his machine and routine maintenance. A 24 hour emergency cover procedure for breakdowns was agreed with the manufacturers and every action carried out on each machine was accurately recorded for future assessment.
- Flow measurement - The flow in each channel was constantly measured and recorded to assess the flow distribution across the works inlet, ensuring that no one machine was receiving substantially more flow than another.

The four screen machines were also evaluated for:

- Screen Name/Definition
- Installation
- Unit Cost
- Maintenance
- Washwater Requirements
- Technical Back-up
- Service/Maintenance Back-up
- Screening Media
- Cleaning Mechanism

The following definitions were used:

Carry Over - The carry over of gross solids by the cleaning mechanism which may then drop into the flow downstream of the screen

Pass-through - Gross solids remaining on the screen after cleaning may be washed forward (passed through) into the flow downstream of the screen

Hairpinning - Where fine and fibrous material becomes wrapped around the wires of screen bars and bridges the gap between the apertures of perforated screens

The screen capture ratio was defined as:

$$= \frac{Y}{(Y + Z)} \times 100\ \% \qquad (2.12)$$

Y = Mass collected on tray inserted into discharge hopper

Z = Mass collected on steel perforated plates or mesh nets inserted downstream

The report recommended that:

- The build up of gross solids on structural sections of the downstream side of the screens caused by carry over should be contained within the screen enclosure, thus preventing the washing down of large congealed screenings into the flow;
- regular maintenance of screens as detailed in the manufacturers/suppliers handbooks should be undertaken;

- all areas of the screen should be easily accessible;
- the deciding factor for the choice of screen should not be cost alone;
- when choosing a screen the conditions at each particular site should be taken into account along with screen effectiveness and reliability;
- evaluation of fine screens should continue as new designs enter the market.

The main conclusions from the trials were:

- The screen capture ratio for each machine obtained during the trials varied with the differing methods employed. However, the ranking order of the screen capture ratios for the four machines remained consistent with the Brackett Green Finescreen having the highest screen capture ratio, the order being:

  Brackett Green Finescreen

  FSM Finescreen

  Bormet Finescreen

  Vickerys Aquaguard

  The Vickerys Aquascreen was found to be no more efficient in terms of screen capture ratio than the Vickerys Aquaguard;
- screens with 6 mm diameter apertures were found to be more efficient in terms of screen capture ratio than screens with 6 mm slot apertures;
- the trials showed that some manufacturers underestimated the requirements of screening equipment. Poor installation, lack of good engineering practice and incorrect choice of materials were common;
- the carry over and pass-through of gross solids was seen as inevitable with screens of this type (fine screens);
- material selection, material thickness, hole spacing and washwater requirements were found to be critical for screens with 6 mm diameter apertures to reduce the tendency for hairpinning;
- It was concluded that since holes had been found to be more efficient in terms of screen capture ratio than slots and the FSM Finescreen had been more

mechanically reliable than the Brackett Green Finescreen, then the FSM Finescreen was to be recommended as the most suitable choice for future large and/or coastal screen installations within Northumbrian Water. Any other screens considered worthy of evaluation should, therefore, be assessed against the FSM Finescreen.

2.1.11 Brown J M, March 1994

The report reviewed screening practice within Yorkshire Water at that time and examined the screening equipment available to establish which machines were suitable to satisfy the Company's future needs and also meet regulatory requirements. It was felt that the general philosophy behind sewage screening had changed from one of removal of larger troublesome material to a reasoned application of a process to protect primary and secondary processes, sludge treatment, and the receiving watercourse. This change had been made more urgent by NRA moves to improve the quality of discharges from CSO's. Information was gathered by means of a wide ranging literature survey covering recent developments in Europe and the UK and visits to a large number of treatment works in Yorkshire and in other Water Companies to see screening equipment. It was found that Water Companies were developing screenings policies in order to meet new NRA regulatory requirements, reduce operational input and improve treatment efficiency and were moving towards increased usage of fine screens.

It was noted that fine screens may impose head conditions sufficient to cause premature operation of upstream overflows, deposition of grit immediately upstream of the screen face may become a problem when the flow velocity is significantly reduced by the head loss. Inlet channels with steep gradients generating high flow velocities may cause damage by imposing too high a loading on the screen.

A high proportion of the bar screens in use within Yorkshire Water were found to be poor performers in terms of percentage removal, as were wedge wire drum screens. The Jones & Attwood back-raked vertical bar screens, in particular, were found to be un-reliable, although the report did not state how the percentage removal or reliability of the screens had been evaluated. Perforated steel band screens, tube screens and 'D' screens were perceived to offer the necessary performance for the future, but the basis for this evaluation was not clear.

The report recognised that as a result of NRA pressure, Formula 'A' overflows would form a new area of screenings operations, although the number of screened overflows which would be regarded as unsatisfactory by the NRA, either from the aspect of spill frequency or that of amenity could not be estimated. It was recognised, however, that improvements may be necessary on all such overflows which discharged to rivers with moderate to high amenity values.

The report suggested there was a need to specify screen size in two dimensions with the move towards fine screening away from bar screens defining fine screening as screens which passed the NRA's 6 mm aperture standard, medium screening as screens passing the 10 mm bar screen standard, and coarse screening as any system which was less effective.

2.2 Previous Work on Aesthetic Pollution from CSO's

2.2.1 Mutzner H, 1987

In Switzerland, watercourses near cities are very important for recreational and aesthetic purposes, gross solids from CSO's are, therefore, undesirable. A small river near Zurich was investigated during the summer of 1986. The investigation was carried out to establish the length of time gross solids discharged from a combined sewer overflow remained visible along the riverbank after an overflow event. Ten overflow events occurred during the study, each overflow duration was measured and the gross solids discharged were counted, the maximum overflow discharge and overflow volume for each event were calculated from rainfall records.

The investigation found that:

- Gross solids trapped by bushes remained visible for several days, whereas on the river banks were soon covered by grass.
- The aesthetic pollution along the riverbanks decreased continually downstream of the overflow structure.
- The greater the gross solids load discharged from the overflow structure, the further downstream aesthetic pollution occurred.
- Bushes sited quite a distance downstream of the overflow structure caught a high proportion of gross solids, the heaviest pollution being observed on a willow bush 800 m downstream.
- No relationship was found between the amount of gross solids observed and the antecedent dry weather period, the time of day, overflow duration or maximum discharge

The paper concluded that the long term effects from gross solids discharged by combined sewer overflows could not be solved by simply reducing the frequency and volume of spill but with CSO structures capable of separating gross solids. Mutzner concluded that the structures most commonly used in Switzerland, the low side weir and the leaping weir overflow , were unsuitable for separating gross solids.

2.2.2 O'Sullivan, March 1990

The report reviewed the subject of CSO performance from the aesthetic point of view. An increase in the need for effective control methodologies for the future was anticipated with increasing public concern at the incidence of sewer derived gross solids in and alongside watercourses, together with statutory water quality objectives and a new regulatory framework. The report concluded that:

- There was a shortage of information about the quantities of gross solids discharged from CSO's;
- There was a similar lack of field information about the performance of different types of overflow structure in terms of their retention of gross solids;
- There was no consistent approach to the use of screens on CSO's.

The report recommended:

- Further research on the effectiveness of different types of overflow structure in retaining gross solids within the sewer system;
- Further research work to evaluate the effectiveness and viability of screens at CSO's. This would enable designers to carry out a cost/benefit type of analysis for screening at overflows.

2.2.3 Realey G J and Eflein H, November 1990

The report describes experiments carried out to determine the removal efficiency of various sanitary products by a sewage screen and to determine if changes to the structure of the sanitary products could improve their removal efficiency. The screen, a Vickerys Aquaguard bar/filter screen (6 mm spacing), was installed in a channel through which water could be passed at a constant rate. The sanitary products or their components were then added to the flow upstream of the screen. Observations were made as to how many of the products/components were captured by the screen and how many passed through. An attempt was also made to identify by what method product/components passed through the screen. In order to simulate the transportation of the sanitary product in the sewerage system, each item was soaked in water for a minimum of 4 hours. Ten items of each product were added to the flow at 15 second intervals until fifty had been tested, the number of items collected by the screen were counted together with those caught on a fine mesh downstream of the screen.

The tests carried out established:

- The sanitary products tested and their component parts had a good screenability;

- A small number of release tapes and plastic elements of the sanitary products were returned to the flow downstream of the screen after adhering to the screening belt.
- When cut into smaller pieces, the release tapes and plastic elements of the products were found to pass through the screen;

The authors made the following recommendations:

- Modification to the glue used in the products and to the surface texture of the plastic components of the screen should be investigated;
- Further work should be carried out into the screenability of sanitary products in sewage pumps and the removal of gross solids in storm overflows;
- Investigations should take place on alternative methods of disposal and if appropriate consumers should be encouraged not to dispose of sanitary products via the sewerage system.

One of the tests carried out by the authors used the plastic components of three products together with the tissue/pulp element of one of the products. The results of this test found that none of the test components showed any sign of disintegration after soaking and that the tissue/pulp was easily removed by the screen. This method of simulation of these products was not representative of their transportation through the sewerage system, the tissue/pulp element of sanitary products is, in practice, dispersed by the flow and held in suspension within the body of the fluid making it difficult to screen out of the flow.

2.2.4 Burchmore S and Green M, March 1993

The report concentrated on the public's perception of riverine pollution caused by gross solids of sewage origin and methods for its minimisation. Three types of approach were used to assess the public's perception of what constitutes aesthetic pollution:

- A literature review;

- Examination of the public complaints registers in Severn Trent, Southern, Thames and Welsh NRA regions;
- Pressure groups (e.g. Greenpeace and Friends of the Earth) and user groups (e.g. British Canoe Union and National Federation of Anglers) were approached for data.

Sewage derived litter was defined as litter which typically enters a watercourse via disposal to the sewer system. Tampon residues, other sanitary products including backing strips, nappy liner remains, grease balls, other plastic items, rags, faeces and cotton buds were given as examples of items of sewage derived litter which may be found in rivers. This type of litter became particularly evident to the general public following high water or flooding events as items were caught on overhanging vegetation. It was found that sewage derived litter was generally viewed by the public as the NRA and Water companies problem. Friends of the Earth, Cymru, however, regarded this type of litter as society's problem.

Examination of the NRA's public complaints registers found that the proportion of sewage related incidents were higher in the Welsh region (26%) compared to the Thames region (18%). The proportion of sewage related incidents reported in Severn Trent, had increased from 7% in 1990 to 30.5% in 1991. Of the incidents reported in 1991 24.3% could be ascribed to sewer overflows, however, the type of overflow was not indicated. Of sewage related incidents in the Thames region only 4.4% (0.8% of all incidents reported) could be directly attributed to CSO's, this figure was found to be 17.3% (4.5% of all incidents) for the Welsh region. It was found that the number of complaints of CSO related incidents remained constant throughout the year.

The authors suggested that the volume of sewage derived litter discharged to receiving waters could be reduced in several ways, for example, by improving the solid retention apparatus at CSO's and sewage treatment works e.g. screens, reconnecting wrong connections and by reducing the inputs of solid material to the sewer system. The report pointed out that present consents are usually worded to reflect the nature of the effluent, the volume of the continuation flow, monitoring capabilities and that the spill flow shall not contain any solid matter capable of being retained on a screen, the aperture of the screen not to exceed a certain size. This size had been found to be 6 mm in some areas (Welsh) and 12 mm in others (Severn Trent). The difficulty with this concept was that it was not clearly understood what was and what was not retained on a 6 or 12 mm screen.

The following recommendations for future work were made by the authors:

- Field study(s) to identify those elements of sewage derived gross solids that the public consider to be detrimental to water quality and to what degree;
- Field study(s) to collect gross solids downstream of a CSO and relate to chemical/biological indices;
- Propose an aesthetic pollution standard and how to monitor compliance together with a strategy for controlling aesthetics at source.

2.2.5 Saul A J, Ruff S J, Walsh A M and Green M J, December 1993

The objectives of the project were:

- To compare the efficiency of a wide range of CSO designs for retaining gross solids within the sewer system under controlled flow conditions;
- To determine the hydraulic conditions under which these CSO structures were efficient at retaining gross solids and the conditions under which performance breaks down;
- To examine the performance of 12 mm and 6 mm bar screens and a 6 mm mesh screen for retaining gross solids within the sewer system.

Six common types of CSO structures were examined:

Sharpe and Kirkbride stilling pond

Extended stilling pond

Single high-side weir

Double high-side weir

Vortex with peripheral spill

Storm King™ hydrodynamic separator

A series of tests were performed using full scale materials to assess the retention performance of different designs of full scale - half scale CSO chambers. Condoms, panty liners, panty liner backing strips and plastic cotton bud sticks were used in the tests to represent those persistent synthetic substances present in domestic sewage. The test materials were manually injected into the inlet pipe of the system and at the mid-depth of the pipe, using a plunger arrangement. One of each type of material were introduced every 20 seconds until 100 of each had entered the system. A 12 mm bar screen, a 6 mm bar screen and a 6 mm mesh screen were tested at the downstream face of the weir of the Sharpe and Kirkbride stilling pond.

The separation efficiency (i.e. proportion of the total gross solids retained in the sewerage system) of all the types of chamber examined was found to be poor at the design flowrate. The efficiency was approximately equal to the overall flow split, giving a treatment factor (i.e. proportion of gross solids retained divided by the proportion of flow retained) of approximately unity. The separation efficiency was found to be significantly better at lower flowrates.

The 12 mm bar screen was found to retain approximately 50-60% of all gross solids passing over the weir compared to approximately 80-90% for the 6 mm bar screen. The 6 mm mesh screen was found to retain all the material presented to it but was prone to rapid blinding and hence required constant cleaning to prevent the overflow weir being drowned. The report concluded that the overall screening efficiency for bar screens was reduced as the bar spacing increased, and in general the removal of panty liners was greater than that of the panty liner backing strips, condoms and plastic cotton bud sticks. The tests highlighted the effects of screen blinding and the need for mechanical raking.

2.3 Previous Work on CSO Monitoring

2.3.1 Saul A J, Marsh P M and Crockett C P, 1989

The paper describes the results of a study to devise a methodology for the short term monitoring of pollutants in sewers, CSO's and storage tanks. The work was carried out to identify procedures for the collection of data and to develop an appropriate strategy for model calibration and verification. It was hoped that sewer quality simulation models, such as, MOSQUITO and WALLRUS could be verified simultaneously.

A CSO structure was monitored for a total of 11 weeks, during this time 9 days of dry weather flow samples were obtained together with data on 5 storm events. The following data were collected:

- A continuous rainfall record;
- Sewer flow at times of storm and dry weather flow;
- Samples of inflow effluent at times of dry weather and storm flow.

The following equipment was used to collect the data:

- Two tipping bucket rain gauges;
- two vacuum jar samplers - one sampler was used to collect samples during storm events, whilst the other collected background samples;
- a WRc swingmeter - which consisted of a 1.0 m rigid aluminium rod with a float at one end and a rotary potentiometer at the other. The float maintained contact with the surface of the water, so a change in flow depth resulted in a change in the angle of the rod, this change was monitored by the rotary potentiometer.
- flow monitor - which recorded the velocity and depth of flow.

The swingmeter and the flow monitor were installed in the first manhole upstream of the CSO chamber. The vacuum jar samplers were manually triggered to withdraw samples at one hourly intervals during dry weather flow. During storm events the operation of the sampler used to collect storm flow samples was controlled by computer software. A suitable water trigger level was established after monitoring the dry weather flow for a period of at least a week. When the water level in the inflow pipe reached the trigger level the computer was programmed to record the output signal from the swingmeter every 60 seconds and set the sampler working. A background sampler operating continuously during storm events collected samples at hourly intervals.

The authors found that the temporal pattern of the pollutants indicated the presence of first and secondary flushes in the concentration and load of pollutants. The pattern of pollutants in the dry weather flow illustrated the expected diurnal variation. The results showed that the temporal load of pollutants at times of dry weather and over the complete duration of a storm event could be reliably monitored with the equipment used. It was concluded, therefore, that the strategy and methodology applied in the control and operation of the monitoring system provided good quality data suitable for model verification.

2.3.2 Walsh A M, 1990

The gross solids sampler GSS was developed by the Water Research Centre following identification of the need to gather data on the behaviour of gross solids at CSO's (O'Sullivan, 1990). The GSS basically consisted of a peristaltic pump with two 100 mm diameter suction and delivery hoses, pumping was initiated by an ultrasonic sensor above the overflow. A set of hydraulic valves automatically alternated flow between the two inlet hoses, another set to the corresponding outlets. The sample was discharged into one of two bins each holding a 6 mm plastic mesh sack (Copasac) which intercepted the particulate matter. The GSS collected a single bulked sample during each operating cycle which consisted of a charge period followed by a maximum of 20 samples to each Copasac.

2.3.3 Jeffries C, 1992

The aesthetic pollution discharged from two combined sewer overflows was investigated using conventional small bottle samplers, trash trap devices and the WRc gross solids sampler (GSS). Visible solids were also collected and counted along a 25 m stretch of the river at one of the CSO sites. The following definitions were used:

Gross solids - faecal matter, particles of paper and any other material greater than 6 mm in any two dimensions with specific gravity close to unity;

Visible solids - material which is identifiably sewage in origin and would be noticed by a casual observer walking on a river bank.

Antecedent Dry Weather Period (ADWP) - the greatest time between periods of filling, although not necessarily causing overflow and spill.

The two overflows investigated were located in eastern Scotland, one overflow was a conventional stilling pond overflow, the other a hydrodynamic separator. The small bottle samplers were used to determine the total suspended solids loadings by sampling the inlet and overflow of each CSO. The trash trap was devised as a passive method of intercepting visible solids to obtain data on the rate of discharge of such material and consisted of one or more diamond mesh screen (24 mm x 8 mm across corners) fixed horizontally on the overflow weir. If severe blinding of the screens occurred the flow could pass over the trash traps taking the gross solids with it. It was found that the trash traps collected two types of solids providing the flow did not by-pass the screens, these being gross solids which comprised faecal matter, sanitary towels, condoms etc. and smaller particles which included shredded paper, foodstuffs and fat particles. These smaller particles together with toilet paper were found to cause a degree of blinding of the diamond mesh apertures.

The composition and nature of the visible solids intercepted by the trash traps was determined by counting and sorting a sample number of events. Plastic and paper strips were found to make up between 76% and 89% of the total sample the average being 82%, the remainder of the sample comprised equal proportions of faecal matter, plastic sticks and condoms. The visible solids obtained from all the events were weighed after being dried for 2 hours. The visible solids collected by hand along the river were found to be virtually all paper and plastic strips with a very small number of faecal solids. Flow rates and volumes together with ADWP were determined at both sites using in-sewer flow loggers.

In agreement with Mutzner (1987) no correlation was found between the number of visible solids collected along the river and the spill volume or peak spill flowrate, however, unlike Mutzner, a correlation was found with ADWP. Good correlation was obtained between the number of visible solids collected and the mass intercepted on the trash trap. Significantly better removal of visible solids was found with the hydrodynamic separator when compared with the stilling pond CSO which would have been expected due to the difference in relative size.

The WRc gross solids samplers (GSS) was installed at one of the CSO's for a 6 month period, data from 22 events were collected during this time. The inlet intake was located in the DWF channel and the overflow intake just upstream from the overflow weir. The majority of events produced small amounts of material in the inlet sack and no measurable weight of material in the overflow sack. A visual examination of the contents from one event found that the material consisted of 50% faecal matter and 50% tampons and associated plastic material. Virtually no condoms or plastic sticks were recovered from the Copasacs.

2.3.4 Lonsdale K, Balmforth D J, Nussey B B & Walsh A M, April 1993

The performance of three types of CSO (stilling pond, high side weir and low side weir) were investigated. The objectives of the research project were:

- To determine the hydraulic character of each overflow chamber investigated and thus the frequency and spill volume of storm sewage to the receiving watercourse;

- To establish the pollution performance of each overflow chamber and therefore determine the effect of the chamber on the transport of pollutants during storm events with particular reference to aesthetically objectionable material;
- To design a monitoring methodology to evaluate the hydraulic and pollution performance of common overflow designs.

Flow data were recorded for each CSO using portable flow survey loggers which were installed, where possible, on the inlet pipe, on the continuation pipe and on the spill pipe. The continuation discharge characteristics of the stilling pond and high side weir CSO's were determined by performing a blocking off test. The test was developed to deal with the interpretation of results from CSO chambers fitted with a continuation throttle where a flow monitor could not be located in either the continuation pipe or in the pipe upstream of the CSO. The continuation pipe of each CSO was closed off during a period of dry weather using a simple plug device and the dry weather flow allowed to back up in the overflow chamber and upstream pipes. Once the flow reached the crest of the weir of the overflow chamber the plug was released. Depths were recorded in the overflow chamber and the next manhole downstream every 15 seconds using field monitors installed in each CSO and a metre rule in the CSO chamber until dry weather flow resumed. The dry weather flow was recorded before and after each test and, where possible, during the filling and release stages.

Suspended and dissolved solid samples were collected using vacuum operated jar samplers. Two samplers were used at each CSO, the intake hose of the first sampled the inflow, whilst the intake hose of the second sampler sampled the spill flow, an external float switch mechanism triggered the samplers. Initially air was pumped down the 10 mm diameter sample tube to flush it free of any obstructions. The sample was then drawn from the flow by a pump into a perspex cylinder on the top of the sampler unit until it reached a pre-set level or volume, the pumping then stopped and the sample was allowed to flow down a distributor arm into one of 24 bottles in the base unit. On completion of the cycle, the arm moved to the next bottle and the process was repeated. After each storm event the base unit was removed and replaced with a new base unit and the samples taken for analysis.

Gross solids samples were taken from a representative portion of the inflow and from the spill flow at each CSO site by using 6 mm plastic mesh sacks (Copasacs). Each Copasac was attached to a metal frame which were then fixed side by side, the positioning of the bags to obtain gross solids samples from the spill flow was dependent on the particular site being monitored. At the stilling pond CSO sampling of the whole of the spill flow was possible, at the other sites the Copasacs were fixed on the weir and only a proportion of the spill flow was sampled. Rainfall was also measured using tipping-bucket rain gauges, one rain gauge was used for each CSO catchment. Visits were made to the CSO sites once a week and after every storm event. During these visits any jar samples and gross solids samples were collected, logged data was downloaded, battery packs were changed and all sensor heads and sampler hoses cleaned.

The discharge through the inflow Copasacs was determined by calculating the mean velocity of flow at each time step and multiplying by the area of the aperture of the submerged Copasac. Discharge through the spill flow Copasacs was obtained by proportioning the flow over the weir to the lengths of the frame to which the Copasacs were attached. The composition of gross solids in each Copasac was investigated and were categorised as follows:

Faecal Material

Sanitary Towels

Thick Paper Towels

Miscellaneous Plastic Material

Leaves, Twigs and Other Organic Material

Absorbent and Non-Absorbent Material

Material Adhering to the Mesh Sacks

The types of gross solids collected at the CSO sites were found to be similar with leaves and sanitary towels identified as the major items, condoms were not observed as a major item. Problems found with the gross solids sampling method included:

- Reduction in the size of the apertures of the plastic mesh due to blinding which may increase the amount of material trapped during storm events giving biased results for certain materials;
- it was not possible to be consistent with the time allowed for draining the Copasacs before weighing;
- Certain gross solids were not adequately sampled by the method e.g. faeces and toilet paper;
- Sampling errors may occur when the whole of the spill flow is not sampled.

CHAPTER 3 FIELD MONITORING OF COMBINED SEWER OVERFLOW SCREENS AND SEWAGE TREATMENT WORKS BAR SCREENS

3.1 Introduction

The performance and efficiency of different types of CSO screens were investigated to enhance the information currently available on screen performance. The experimental programme was broken down into three parts. This chapter deals with a field investigation into the performance and efficiency of existing types of bar screens to establish the quantity of gross solids that will pass a bar screen and to identify the factors which influence screen performance. The experience gained from the work on bar screens was then used to establish the performance and efficiency of different types of screen meshes which is discussed in chapter 4. Chapter 5 deals with laboratory tests carried out on mesh screens to determine head losses.

A field investigation was undertaken on four existing mechanically raked bar screens. The original intention of the work was to monitor two CSOs with different screen arrangements. After an exhaustive search, however, the only screens suitable for monitoring within travelling distance were found to be D-screens with a semi-cylindrical cross-sections. The screens were all installed on stilling pond CSOs and all had 12 mm bars with 15 mm spacings between bars. In order to obtain comparative data on a different screen arrangement another site needed to be found. Attention was turned to sewage treatment works inlet screens, and after an extensive survey and several site visits, a suitable sewage treatment works inlet screen was located. The added advantage of this particular works was the layout of the inlet screens. Two inlet screens, installed parallel to each other, were available for use at the works. By manually opening and closing a series of penstocks the incoming flow could be diverted through either inlet screen. This enabled each screen to be isolated and the whole of the flow entering the works to be screened by one screen. A direct comparison could therefore be made between the two screens, as they handled the same sewage and the same flow rates. Since one of the screens was a D-screen a direct comparison between D-screens and inclined bar screens could be made.

3.2 Requirements for suitable combined sewer overflow sites

Several factors affect the suitability of a combined sewer overflow for the purposes of a field study.

3.2.1 Safety considerations

Structural condition: The age and state of repair of the combined sewer overflow chamber has to be taken into consideration when choosing a suitable combined sewer overflow site. Local authority records should be examined to establish if there are any known engineering defects and/or local hazards in the CSO site or the surrounding sewer system. The CSO site must be in good structural condition including any ladders, step irons, platforms or landings used for entry and exit into the site.

Atmospheric condition: A CSO site should not have a history of poisonous gases and/or toxic discharges in the sewer system upstream of the CSO chamber. Ventilation of the CSO chamber and surrounding sewer system upstream and downstream of the chamber must be possible by lifting manhole covers associated with the CSO without endangering the general public by doing so.

Site entry conditions: The CSO site should be easily accessible preferably away from the highway to enable safe entry and exit from the sewer system. It should be possible to lift the manhole covers with relative ease. The manhole openings allowing entry and exit to the CSO site should be large enough to allow any member of the sewer entry team easy access both into and out of the sewer system. Ideally, the manholes themselves should not be more than 3 m deep, thereby minimising the risk should a member of the sewer entry team experience difficulties and need to escape from the sewer system quickly. The volume and rate of flow should be assessed prior to a site visit. Large volumes and high rates of flow make working conditions hazardous and should be avoided. Not only do dry weather conditions need to be assessed but consideration also has to be given to the speed with which a CSO chamber fills during wet conditions and the distance from the nearest manhole a member of the sewer entry team may have to work. To minimise the risk of being washed away, safety chains should be fitted across the entrance to pipes leading from manholes. If these are not fitted there should be some means of securing personnel within the manhole or CSO chamber. Any CSO site which has evidence of rat infestation should be avoided to minimise the risk of Leptospirosis Weil's Disease

3.2.2 Access considerations

Distance: The travelling time to and from the site should be relatively short due to the nature of the work. Samples need to be classified, weighed and disposed of soon after collection to prevent them becoming a health hazard. Personnel working in the overflow chamber also need to be able to wash and change as soon as possible after leaving the site.

Equipment installation: A CSO site must have adequate working space underground for members of the sewer entry team to install monitoring equipment for flow data measurement and to enable this equipment to be regularly cleaned and maintained. There should also be adequate working space above ground to enable personnel to pass equipment to members of the team working below ground and also to safely download data from flow monitors without endangering themselves or the general public. All monitoring equipment should be capable of being installed in sewers or manholes to limit the possibility of vandalism or theft. It should therefore be intrinsically safe, and there must be enough room within the CSO to house all the equipment once installed.

Sample collection: Gross solids collection must be possible from both the screen and the spill flow, screens which rake the collected gross solids back into the approaching flow are not suitable for monitoring. Again as with the equipment installation, a CSO site should allow adequate working space to enable the installation of frames for the collection of gross solids. Access to the frames should be considered as the collected samples need to be removed for analysis and the plastic mesh sacks (Copasacs) used for sample collection replaced.

3.2.3 Measurement suitability

Flow data: In order to obtain accurate flow data records the location of the flow monitors is very important. The instrument's sensing head needs to be sited in a place of minimal flow disturbance and where ragging up and silting are kept to a minimum, figure 3.1. Flow monitors should be sufficiently far away from sewer junctions to avoid interference caused by combining flows, and pipes or channels which are prone to silt deposition should be avoided. Upstream flow monitors should be placed far enough upstream to measure relatively uniform flow and be free from backwater effects. Likewise, where a throttle is fitted to the continuation pipe, flow monitors should be installed at least one manhole downstream of the overflow chamber. Installation in a throttle pipe is not advisable due to an increased possibility of ragging of the sensor head and subsequent blockage.

3.3 Introduction to the Field Sites

3.3.1 Combined sewer overflows

Potential combined sewer overflow sites were located by liaising with Yorkshire Water, Sewerage & Services and Sheffield City Council, Design & Building Services. A number of possible sites were eliminated immediately due to their location. An initial site visit was made to the other potential sites. A number of suitable sites were rejected because gross solids collection from either the screen or the spill flow or both was not possible. Side weir CSOs were rejected because the gross solids were back

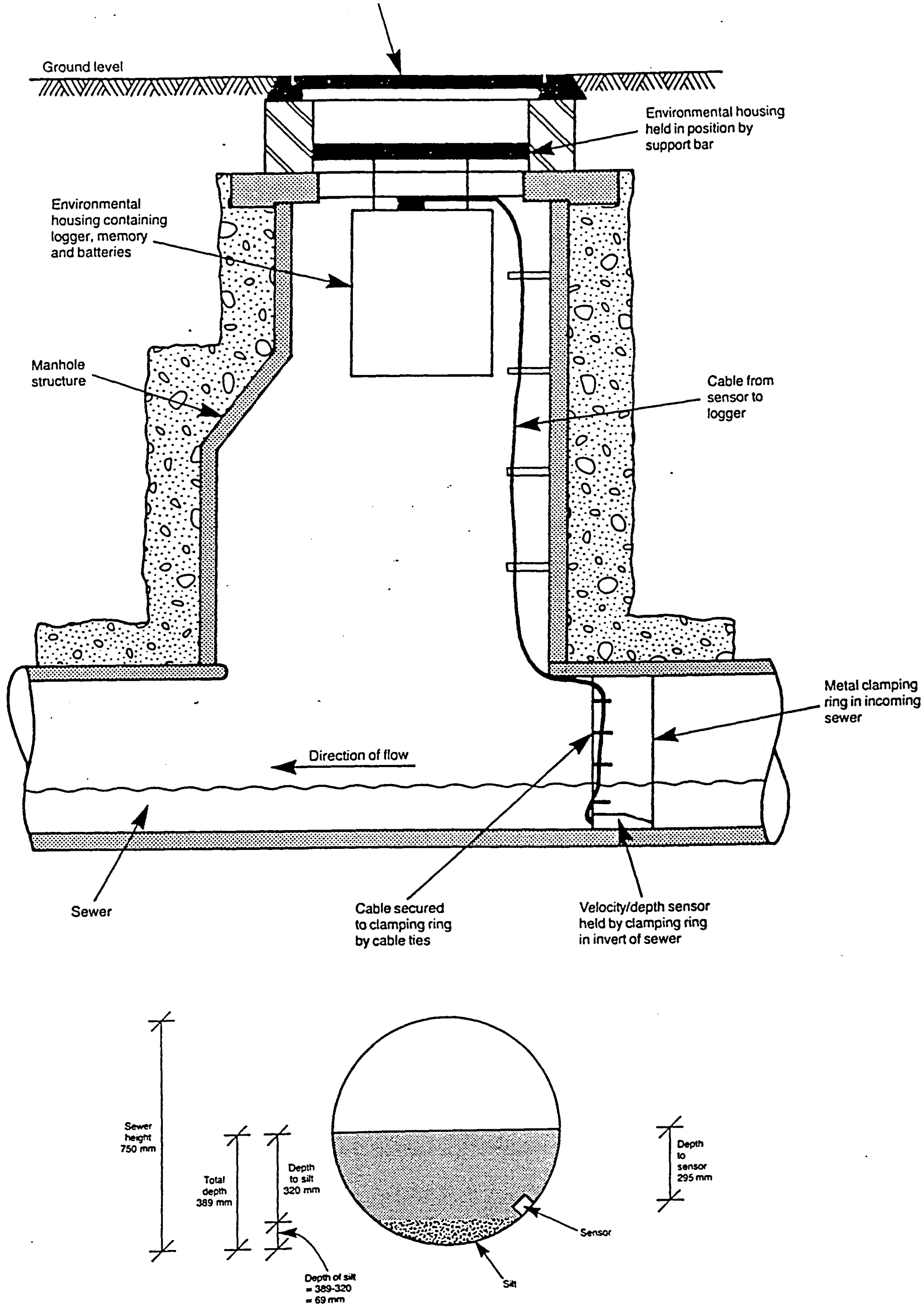


Figure 3.1 Flow Monitor sensing head placed in a place of minimal flow disturbance

raked into the approaching flow making it impossible to collect the samples. A prospective CSO site with a rotating drum screen was visited, however, like the side weir CSOs, the gross solids were returned to the flow making sample collection impossible. Other prospective sites inspected were abandoned after access conditions and possible monitor locations were found to be either awkward or impossible.

The two sites finally chosen for the project were both stilling pond overflows with D-screens having 12 mm bars and 15 mm spacings between bars. Both screens were mechanically raked with a two-rake rotary mechanism, which raked continuously from the upstream side of the screens during a storm event, figures 3.2 and 3.3. One CSO was a Sharpe and Kirkbride stilling pond and the other an Extended stilling pond. Both CSO's were within easy access of Sheffield Hallam University and both were located away from the public highway. Manholes at both the sites could be lifted easily without endangering the public, both sites were structurally sound and the upstream and downstream sewerage system of each CSO could be vented during each site visit.

The monitoring periods for both sites were as follows:-

Sharpe & Kirkbride stilling pond	March 1992	to	September 1992
Extended stilling pond	October 1992	to	December 1992

Drawings of the two sites are given in Figures 3.4 to 3.5. Plans showing the location of the combined sewer overflows and the surrounding sewerage system, obtained from Sheffield City Council, Design & Building Services are given in Figures 3.6 and 3.7.

The Sharpe & Kirkbride stilling pond is situated in an area of open ground off Sheaf Bank in Sheffield, the overflow pipe discharges directly into the River Sheaf. The catchment area of 53.3 hectares is largely residential with a fall of 83 m over its

Figure 3.2 Sharpe & Kirkbride Stilling Pond D-screen

Figure 3.3 Extended Stilling Pond D-screen

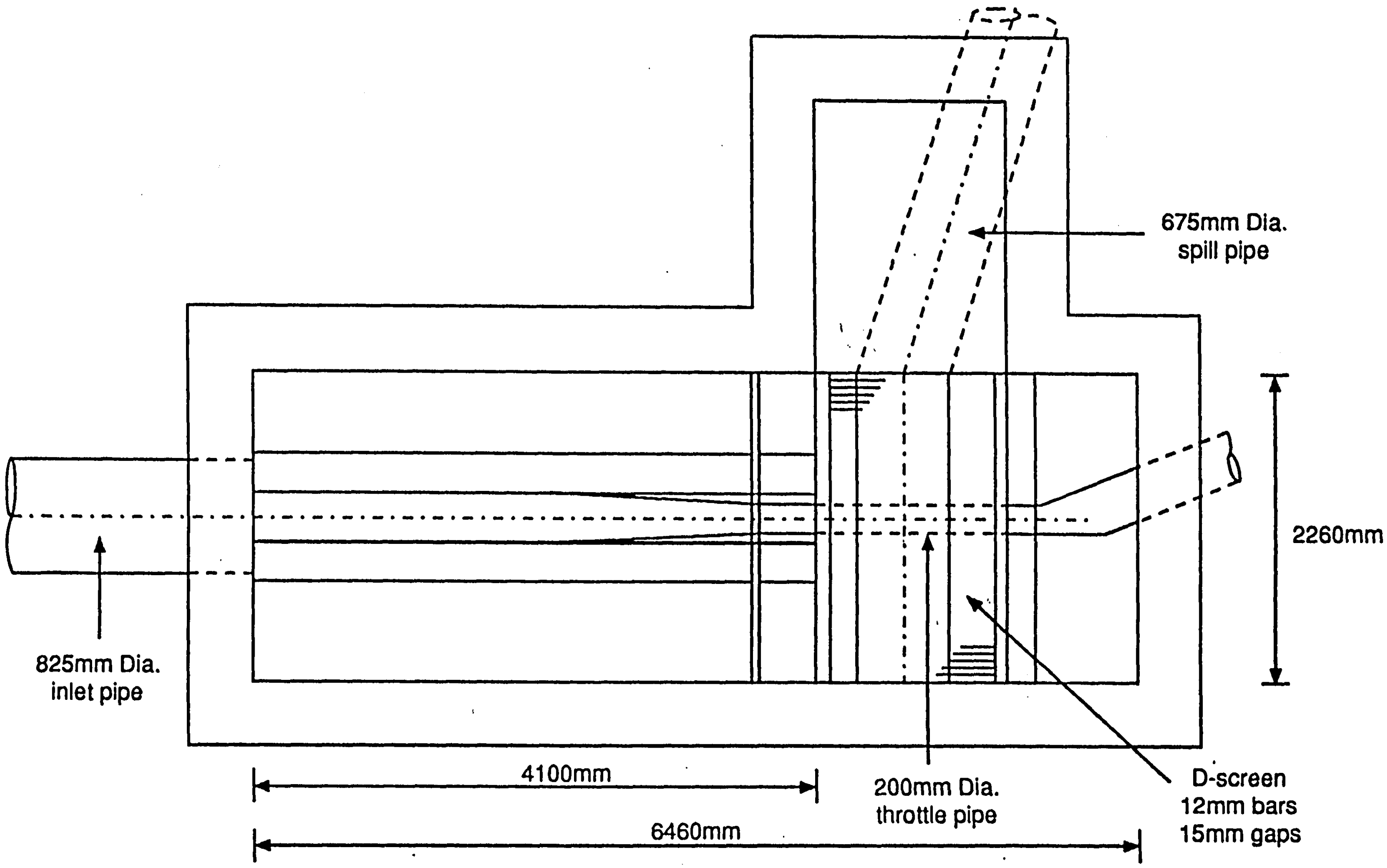


Figure 3.4 Plan of Sharpe & Kirkbride Stilling Pond CSO

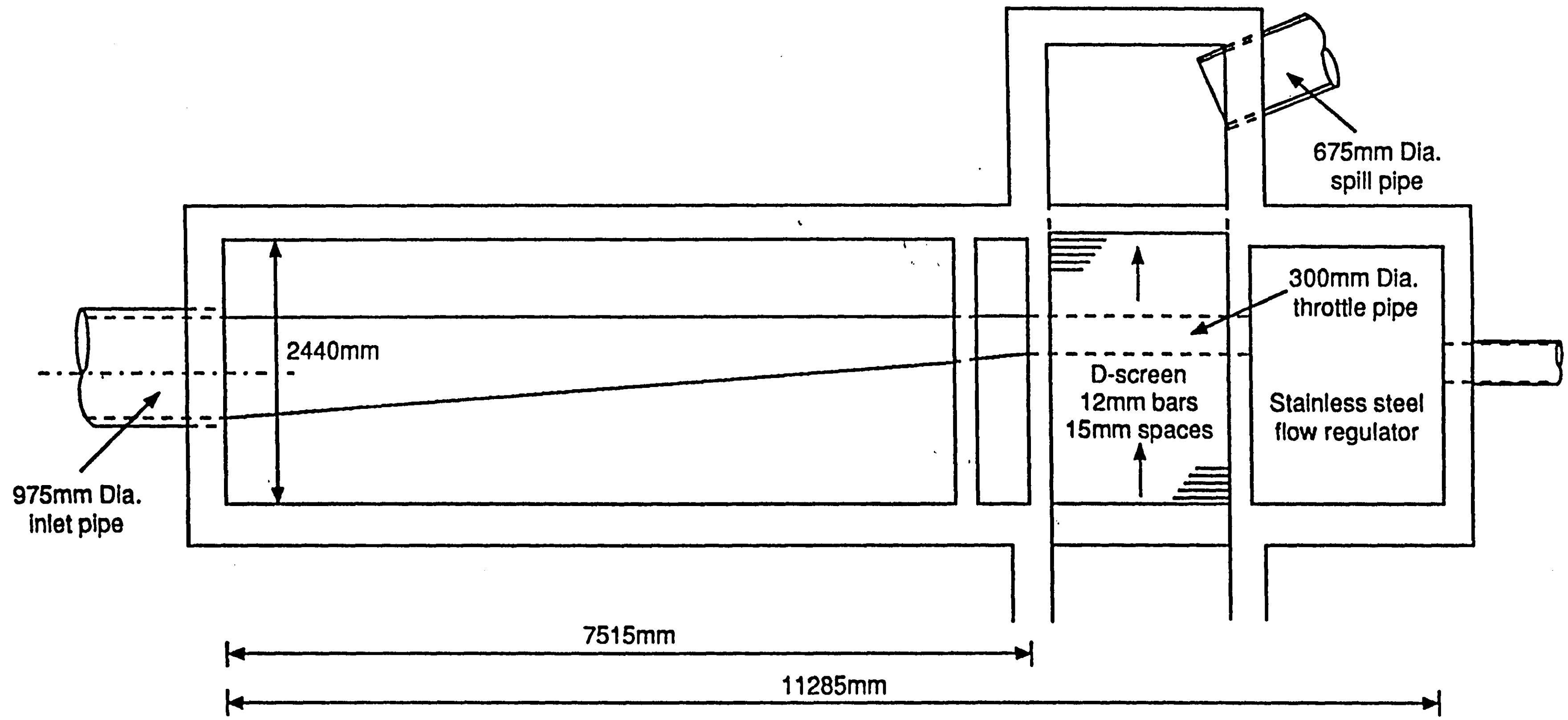


Figure 3.5 Plan of Extended Stilling pond CSO

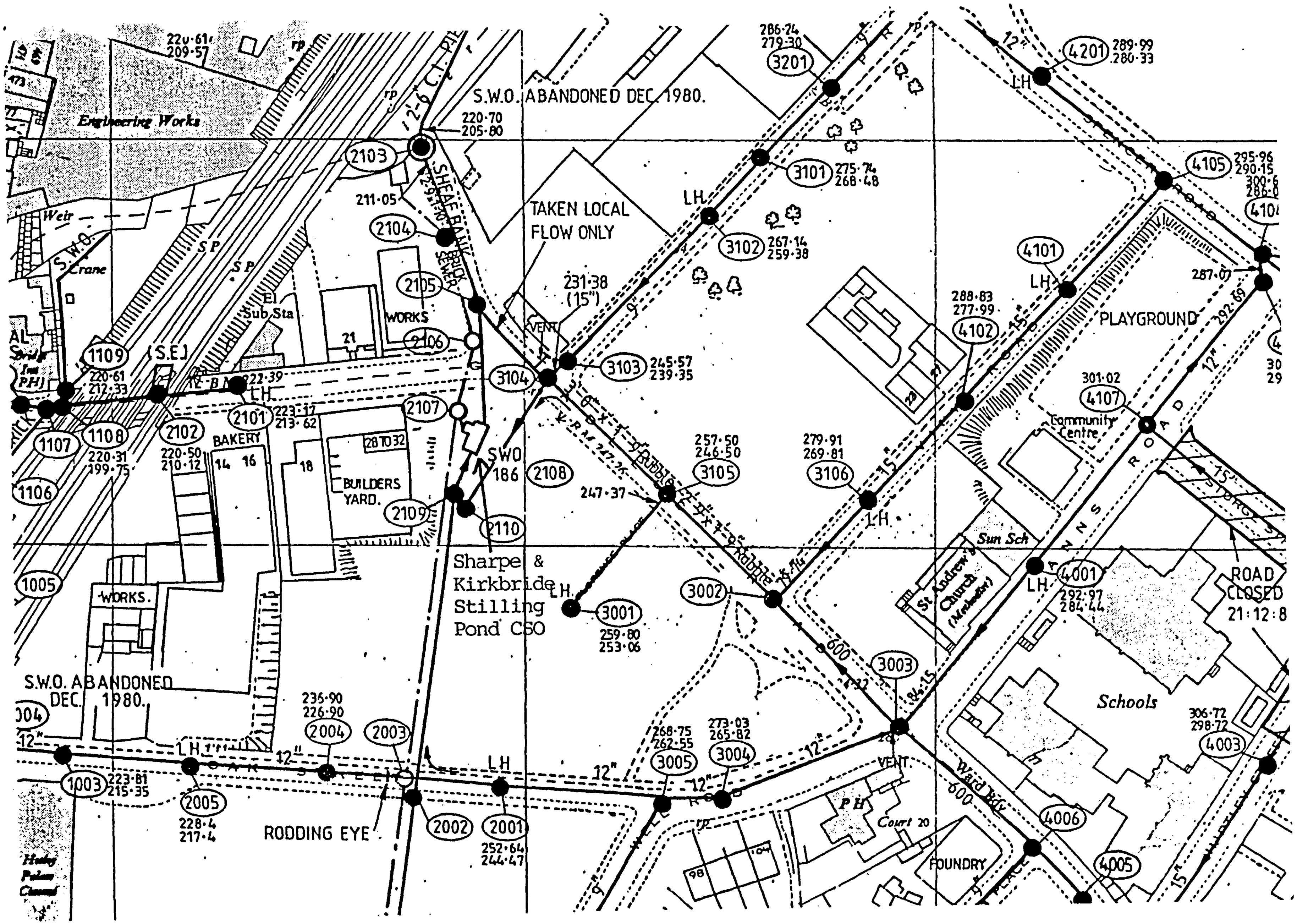


Figure 3.6 Location of Sharpe & Kirkbride Stilling pond CSO

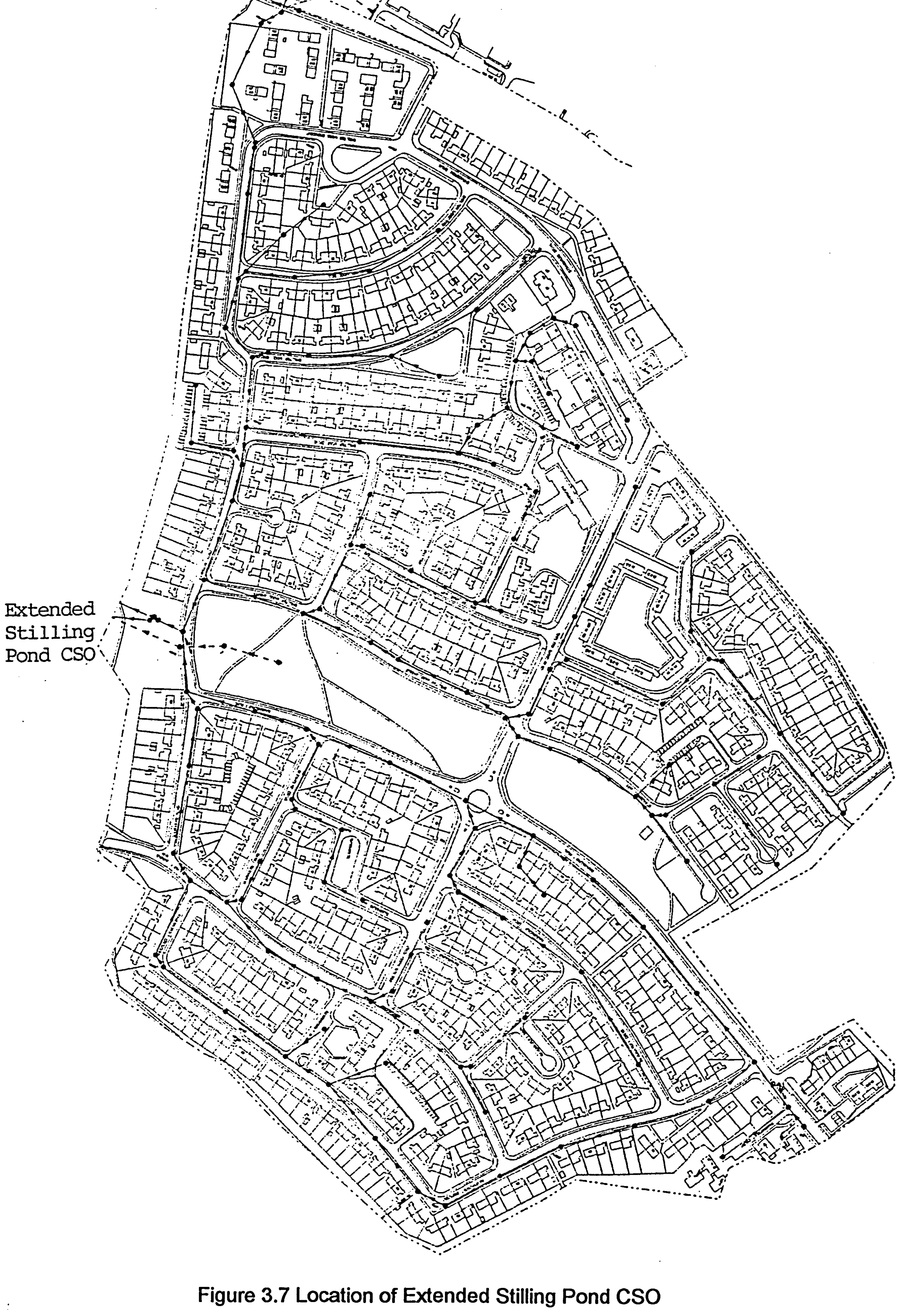


Figure 3.7 Location of Extended Stilling Pond CSO

1.85 km length (1 in 22.3). The D-screen of the overflow is located on the crest of the overflow weir and gross solids retained on the screen are raked off the screen and dropped back into the continuation pipe. A throttle pipe controls the passed forward flow and the CSO chamber is fitted with a scumboard.

The Extended stilling pond is located just off Glenholme Road in Sheffield in a piece of waste ground, the overflow pipe discharges into the Shirtcliff Brook. The catchment area is smaller than the other CSO site, being only 38.5 hectares, and is also predominately residential with a fall of 41 m over its 800 m length (1 in 19.5). The D-screen of the overflow is located on the crest of the overflow weir, a stainless steel tray is permanently fixed downstream of the screen to collect the gross solids mechanically raked off the screen. The tray is flushed clean by a gully during a storm event, thus returning the gross solids to the continuation flow. The CSO chamber is fitted with a scumboard and the passed forward flow is controlled by a stainless steel vortex regulator.

The hydraulic performance of the two combined sewer overflow structures was monitored by measuring flows and depths of inlet, continuation and overflow outlets where possible. The gross solids retained on the screens were collected along with samples of gross solids from the overflow pipe downstream of the screens. The samples were classified into different categories and weighed wet in order to determine the proportion of material retained by the screens.

3.3.2 Sewage treatment works

Long Lane sewage treatment works is served by Brinsworth, Catcliffe, Canklow, Treeton and Whiston. The catchment area is mainly residential and there is a high proportion of open land. The sewage has a pumped inlet via four rising mains. Pumping of the sewage is intermittent from four pumping stations and no maceration of the sewage takes place prior to it entering the works. A drawing of the inlet to the works is given in figure 3.8.

Long Lane sewage treatment works has two inlet screens which have been installed parallel to each other. One screen is a D-screen with 25 mm spacings, the screen is mechanically raked with a semi-rotary reciprocating single rake, figure 3.9. The other screen is an inclined straight bar screen, the bars being spaced 6 mm apart. The screen is inclined at 75 to the horizontal and is continuously raked by a set of tines mounted on a moving endless chain, figure 3.10. Under normal operation the flow entering the works is screened by the D-screen. However, the whole of the flow can be diverted into a side channel where the inclined bar screen is installed. The gross solids retained by both screens are deposited at the top of their travel onto a conveyor belt installed behind the screens above the flow. The gross solids then drop into a skip positioned under the end of the conveyor belt. Once the flow entering the works has passed through one of the screens it enters the primary settling tanks via a rectangular channel.

A great deal of time was spent during June and July 1993 obtaining access to the site and ensuring the inclined bar screen was operational. Preliminary site visits were made during July 1993 and access to the site was granted in August 1993. A working schedule was produced which gave details of the method of testing and the equipment that would need to be installed in order to carry out the work and this was issued to Yorkshire Water at the beginning of September 1993. The equipment was installed at the site on 7th September 1993. Testing commenced on 14th September 1993 and was carried out 4 days a week, weather permitting, until 10th November 1993.

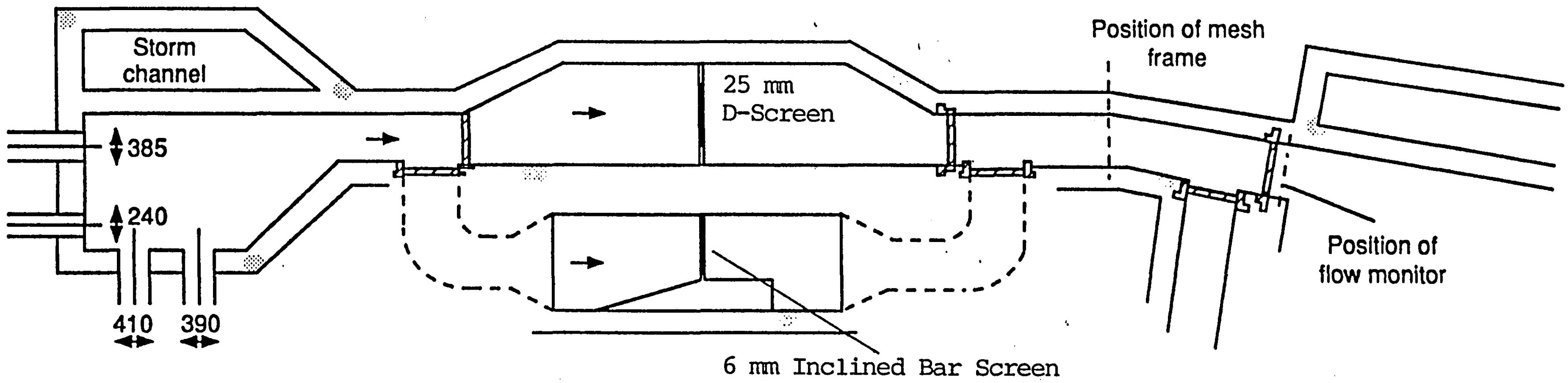


Figure 3.8 Plan of Long Lane STW inlet

Figure 3.9 Long Lane STW Mechanically Raked D-screen

Figure 3.10 Long Lane STW Inclined Straight Bar Screen

3.4 Monitoring Equipment

Detectronic intrinsically safe flow monitors were used at each CSO site. These are transportable/temporary monitors capable of measuring and storing the velocity and depth of flow for a limited period of time, in a digital form suitable for use in a detailed computer analysis. The monitors consist of four main components - a sensor, a processor, a data logger and a power supply, figure 3.11. Velocity transducers located in the sensor measure the fluid velocity by means of a Doppler meter. A continuous ultrasonic signal is emitted at a fixed frequency, which is reflected by particles and air bubbles in the flow, and its frequency is changed by an amount dependent on the speed of movement. A receiver detects the reflected signal, the two signals are compared and by using the Doppler principle the frequency difference between them is translated into a velocity. Fluid depth is measured by a pressure transducer, again located in the sensor of the monitor, and recorded as a pressure head. The pressure difference between the sewage and atmospheric pressure, introduced by a breather tube at the back of the sensor, is measured by the strain on a silicon diaphragm contained within the transducer. The flow monitor activates the transducers at programmed intervals. Pressure transducers are prone to drift over a period of time so regular depth checks must be made using alternative instrumentation.

A Husky Hunter portable computer was used to download the data from the flow monitors and transfer it to a personal computer. The WRc Sewer Survey Analysis Software (SSAS) was used to process the data. Pipe shapes and sizes, and other details of the sites monitored were entered into the software. The flow monitors were programmed to record at two minute intervals during dry weather flow but during a storm event this was reduced to 15 seconds to obtain more detailed data of each particular storm. SSAS could only deal with data measured at a rate of one minute or more, consequently a computer spreadsheet was used to calculate flowrates.

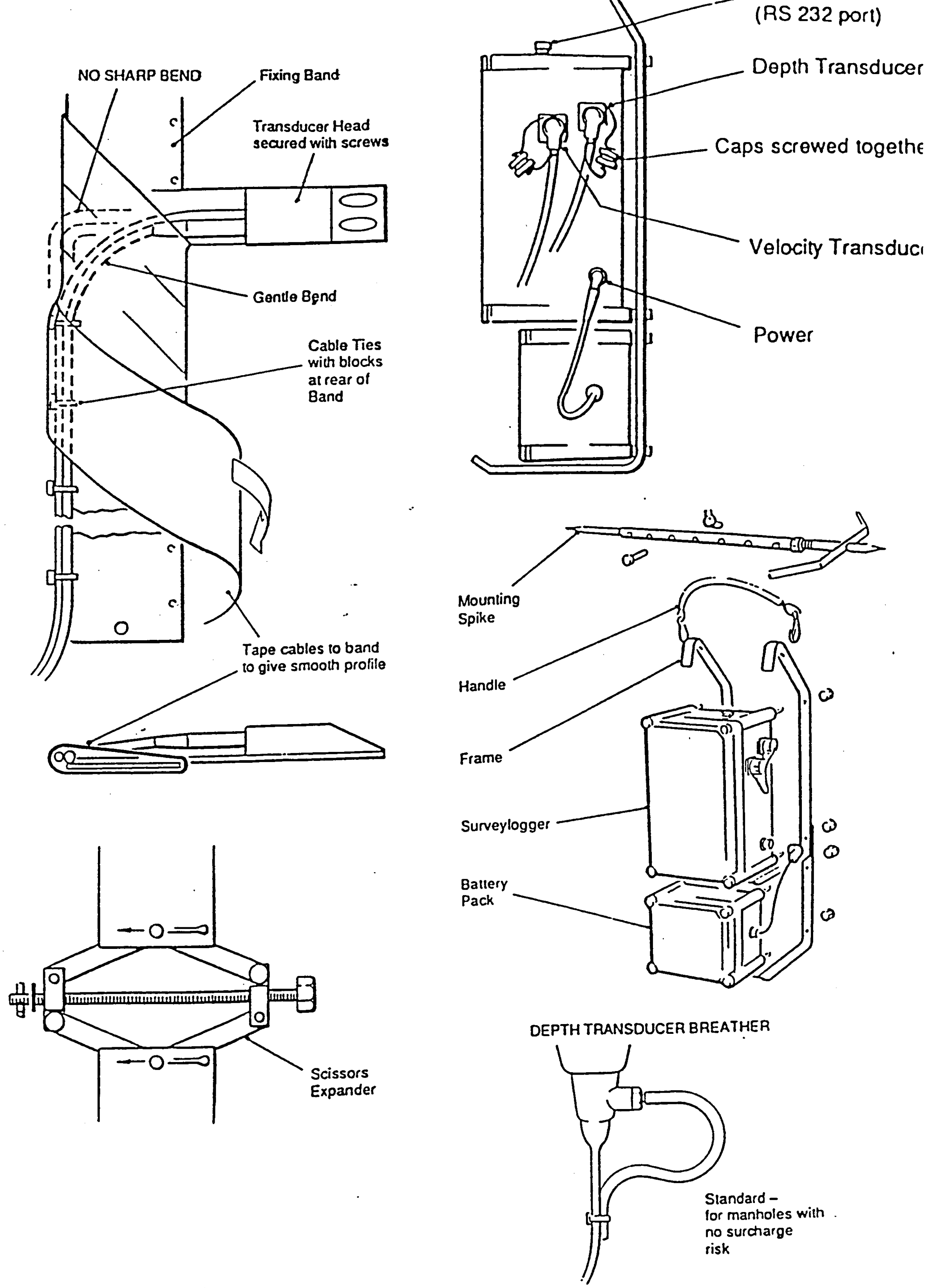


Figure 3.11 Components of a flow monitor

Before the flow monitoring equipment was installed in any of the monitoring sites it was tested in the Hydraulics Laboratory to check the depth calibration and ensure the depth and velocity readings were within the tolerances stated in the manual:

Depth   at best 2-3 mm and typically 5-15 mm

or 1-2 % of the reading whichever is the greater.

Velocity   10-20 %.

If the battery voltage of the flow monitor falls below 8 volts then the readings become inaccurate.

The flow monitors were found to have velocity readings within ± 5% of the actual velocities and depth readings within ± 2 mm (± 0.8%) of the actual depth readings during the tests carried out in the Hydraulics Laboratory. This testing period also enabled personnel to familiarise themselves with how to start the instrumentation logging, how to retrieve data and how to clear the monitor memory before using the equipment on site. This ensured that none of the field data was lost through operator error.

Throughout the duration of the project safety procedures for sewer entry were adhered to. A sewer entry team was formed, all of whom were trained for working safely in confined spaces. This included being familiar with gas detection instruments and the correct procedure for operation and being able to use breathing apparatus under working and escape conditions. Knowledge was also needed of all the personal equipment (e.g. harnesses) and other equipment (e.g. ropes, winch, road signs etc.) necessary for safe entry into a sewer. In addition to this training all members of the team were inoculated against hepatitis A, polio, tetanus and typhoid and all were required to take a lung function test to ensure they were capable of using the breathing apparatus.

3.5 Monitoring Equipment Installation

3.5.1 Sharpe & Kirkbride stilling pond

Two flow monitors were installed, one to monitor the flow entering the overflow chamber and the other to monitor the spill flow. The inflow monitor sensor was positioned in the overflow chamber approximately 1.0 m into the inflow pipe. The transducer sensor head was fastened with screws to a stainless steel band and the band fixed to the invert of the inflow pipe, figure 3.12. Care was taken to ensure that the monitor sensing head was lying flat to minimise the collection of debris. Siting the transducer further upstream of the overflow chamber was not possible due to the upstream sewer configuration causing turbulence. Small nylon cable ties were used to lace the cables to the trailing edge of the band. The cables were then fixed along the wall of the overflow chamber using cable clips and the flow monitor housing the data logger, processor and power supply was hung from a step iron in the overflow chamber manhole to prevent the unit from being surcharged. The excess cabling was coiled and tied beneath the housing.

The transducer sensor head for the spill flow monitor was installed in the downstream end of the spill pipe approximately 0.5 m into the pipe and approximately 5.0 m from the overflow chamber, figure 3.13. Again the sensor head was fixed to a stainless steel band which was screwed to the invert of the spill pipe. The cables from the sensor head were clipped to the spill chamber wall and the flow monitor hung from a step iron in the spill chamber manhole in a similar manner to the inflow monitor.

A rectangular dexion frame was constructed behind the screen, downstream of the overflow weir and 6 mm Copasacs were cut open to provide a single layer of plastic mesh which was fastened across the frame using cable ties. Thus forming a net to collect the gross solids being mechanically raked off the screen during a storm event, figure 3.14. The sample could then be transferred by hand from the Copasacs to a bin liner for analysis.

Figure 3.12 Location of Sharpe & Kirkbride Stilling Pond inflow monitor

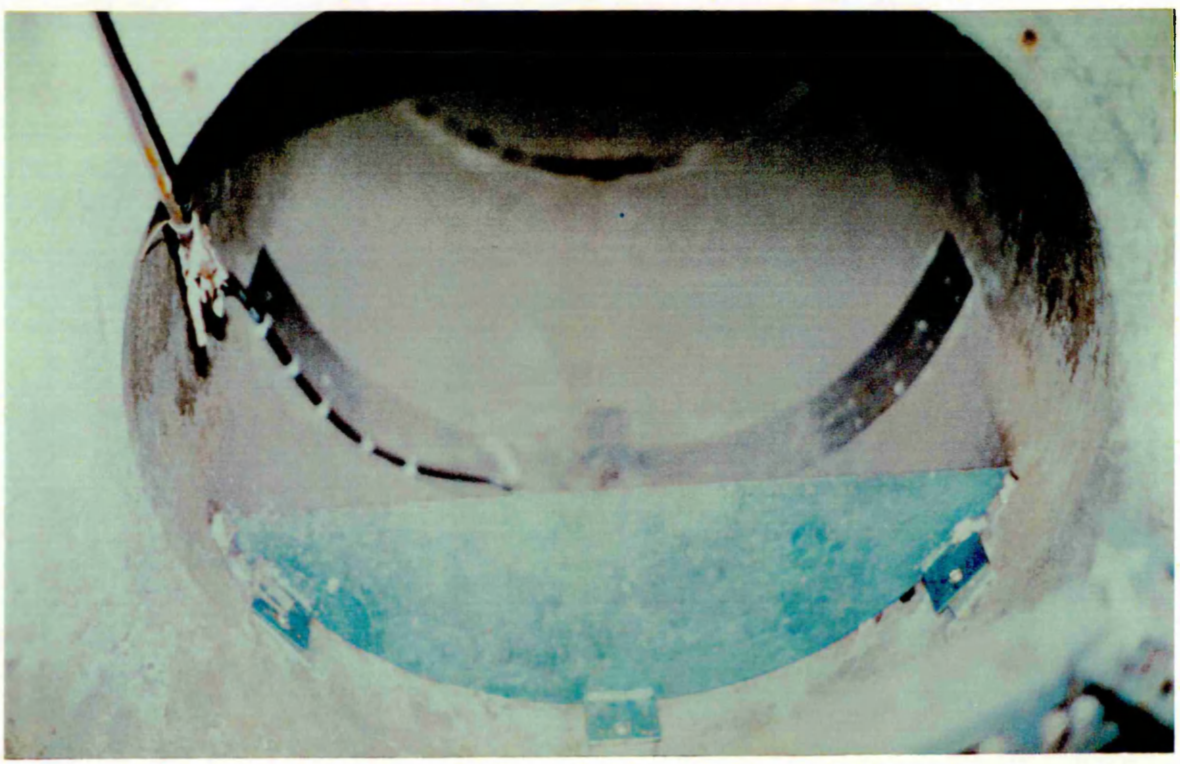


Figure 3.13 Location of Sharpe & Kirkbride Stilling Pond spill flow monitor

Figure 3.14 Copasac frame built behind Sharpe & Kirkbride Stilling Pond D-screen

A dexion frame was also built at the downstream end of the spill pipe across the spill chamber. The frame held a one inch steel mesh to which cut and opened out Copasacs were attached using cable ties to collect any gross solids which passed through the screen during a storm event, figure 3.15. The Copasacs were removed and replaced after each storm event and taken back to the laboratory for analysis. The frame was constructed so that the flow could spill over the top of the frame. This prevented surcharging of the system upstream of the overflow chamber, should the Copasacs blind causing backing up of the flow behind the frame.

3.5.2 Extended stilling pond

Monitoring of the inflow was not possible due to the upstream sewer arrangement. To avoid the very low velocities and reverse flow associated with backwater effects the monitor needed to positioned further upstream of the overflow chamber. The inlet sewer, however, meets a T-junction further upstream which meant a flow monitor would have to be placed in each branch of the T in the next upstream manhole. Unfortunately only two flow monitors were available and one monitor was required to measure flow data downstream of the overflow. Consequently the continuation flow and the spill flow were monitored using the two flow monitors. The transducer sensor head for monitoring the continuation flow was fixed to an expandable stainless steel ring which was inserted approximately 0.5 m into the continuation pipe using the access chamber of the first manhole downstream of the screens. Using a scissors expander the ring was securely clamped upstream of the access chamber with the sensor lying flat on the sewer invert, figure 3.16. The flow monitor was hung from a hook which was screwed to the wall of the access manhole and the sensor head cables were fastened to the wall of the access chamber. The spill flow transducer sensor was positioned in the spill chamber approximately 1.0 m into the spill pipe. The sensor head was attached to a stainless steel band and fixed to the invert of the upstream end of the spill pipe, figure 3.17. The flow monitor was hung from the spill

Figure 3.15 Sharpe & Kirkbride Stilling Pond spill frame

Figure 3.16 Extended Stilling Pond continuation flow monitor

Figure 3.17 Extended Stilling Pond spill monitor

Figure 3.18 Stainless steel tray built behind Extended Stilling Pond D-screen

chamber manhole in a similar manner to the continuation flow monitor and the sensor head cables fixed to the spill chamber walls using cable clips.

A small, rectangular steel frame was constructed at the end of the stainless steel tray downstream of the screen and a Copasac attached to it to collect the gross solids retained by the screen, figure 3.18. It was found that this frame and Copasac were actually surplus to requirements as the gully washing the stainless steel tray was inefficient and the gross solids remained in the tray and were subsequently collected from it.

A dexion frame similar in design to the one used at the Sharpe & Kirkbride stilling pond was constructed across the spill chamber at the upstream end of the spill pipe and a single layer of Copasac mesh was fastened to it with cable ties, figure 3.19. An inspection was made during a rainstorm event to ensure the spill flow did not overtop the frame, thus all the gross solids passing through the screen were collected in the spill chamber. As with the Sharpe & Kirkbride stilling pond, the frame was constructed to ensure the flow could overspill the frame as a safety measure should the Copasac blind and cause surcharging upstream.

3.5.3 Long Lane sewage treatment works

The four pumping stations serving the sewage treatment works did not pump continuously, only one pumping station operating at any time. The installation of a flow monitor upstream of the screens was impractical due to the turbulence caused by the intermittent pumping and subsequent backsurge in the inlet pipes which were not pumping. The flow monitor was therefore installed in the rectangular channel downstream of the screens leading to the primary settling tanks. This enabled measurement of the flow passing through the screens. The transducer sensor head was fastened to the shortest leg of an L-shaped band and the longest leg was screwed onto the channel wall, figure 3.20. The sensor head cables were fastened to

Figure 3.19 Extended Stilling Pond spill frame (without Copasac)

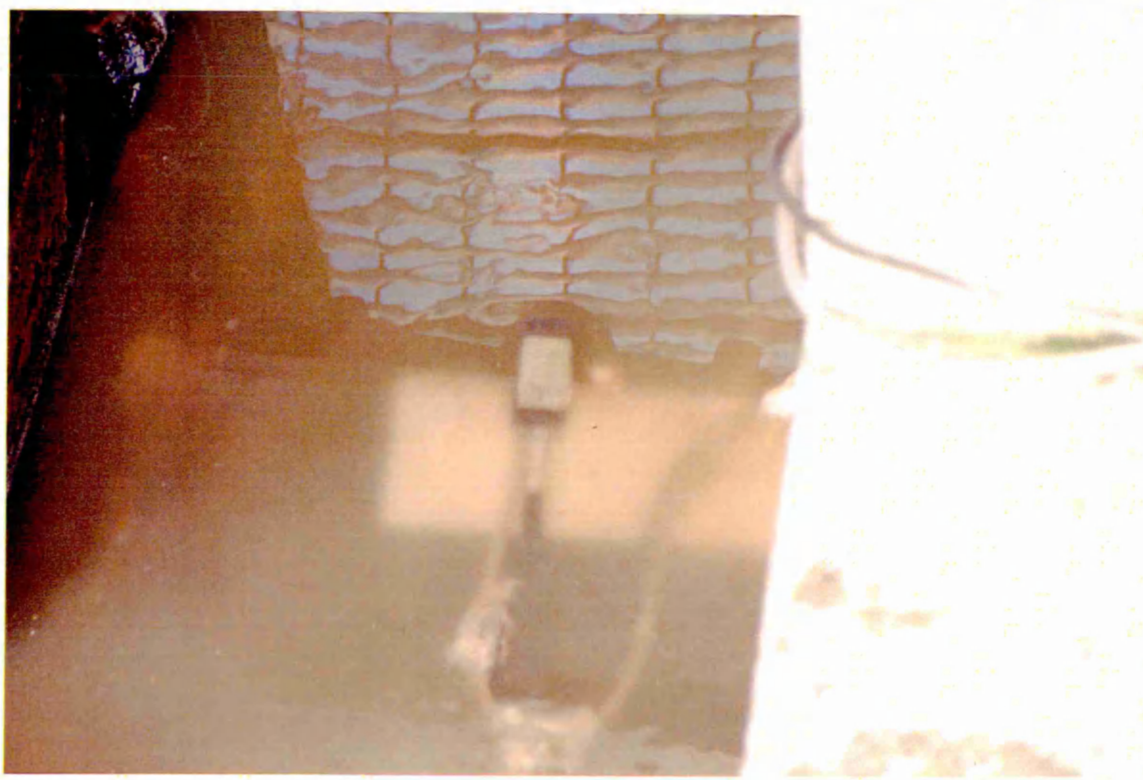


Figure 3.20 L-frame for Long Lane STW transducer head

the wall of the channel and the excess cabling was coiled and hung on a hook fixed to the wall of the storm channel adjacent to the main channel. By positioning the cable here the equipment was obscured from view The flow monitor was installed and removed each site visit for security reasons, leaving only the transducer sensor head permanently on site.

Steel runners were fastened to the sides of the channel downstream of both screens and a rectangular frame was manufactured which could be manually inserted between these guides. A piece of one inch steel mesh was fixed to the frame using cable ties to which a cut and opened out Copasac was attached, figure 3.21. By inserting the frame into the screened flow any gross solids which passed through either screen could be collected. A platform was manufactured from dexion and plywood which fitted across the skip underneath the drop off point of the conveyor belt to collect the gross solids retained by the screens, figure 3.22.

3.6 Methodology

3.6.1 Combined sewer overflows

Both combined sewer overflows were visited weekly to download the field data from the flow monitors, to change the batteries which powered them, and to take independent depth and velocity readings to check monitor calibration. The transducer heads were checked and cleaned if necessary and the gross solids' collection receptacles examined for any defects. Site visits were also made after significant storm events to collect any gross solids which may have been deposited on the collection receptacles.

The first few rainstorm events highlighted monitoring problems in the spill pipe of the Sharpe and Kirkbride stilling pond. The relatively steep gradient of the spill pipe was producing high velocities with low depths. False data readings were recorded by the flow monitor due to the transducer head breaking up the flow at these shallow depths.

Figure 3.21 Capture frame between guides at Long Lane STW

Figure 3.22 Skip platform at long Lane STW

Consequently a small weir was introduced into the spill pipe to allow the flow to back-up thereby reducing velocities and increasing depths. This prevented the flow breaking up over the transducer sensor head and eliminated the false data readings.

A blocking-off test was performed at the Sharpe and Kirkbride stilling pond to determine the continuation discharge characteristics (Lonsdale et al, 1993). The throttle pipe of the chamber was blocked off with a steel plate held in position between metal guides to allow immediate release once the dry weather flow reached the crest of the weir. A net filled with rags was inserted into the throttle pipe to create a tight seal around the plate. Once the backed-up sewage was released, depth readings were recorded in the chamber at 15 second intervals until dry weather flow resumed. These depths were taken manually in the stilling chamber using a metre rule and also from the inflow monitor which was set to record at 15 second intervals. The dry weather flow was also recorded before and after the test.

The frame initially built across the spill chamber at the Sharpe and Kirkbride stilling pond consisted of a rectangular dexion frame holding a one inch square steel mesh. The frame was drilled, plugged & screwed to the concrete walls of the spill chamber. However, the frame was destroyed during two rainstorm events. The frame construction was strengthened using Rawl-bolts instead of screws and inserting two bracing members perpendicular to the frame. This design prevented the dexion frame being destroyed but the steel mesh was forced out of position during a subsequent rainstorm event. Two vertical bracing members were introduced to provide support for the steel mesh and this design proved able to withstand the force of the water entering the spill chamber.

Calibration checks were always made during each site visit, manual depth readings were taken using a metre rule held in the flow and velocity readings were taken using a hand held propeller velocity meter. The insitu measurements were recorded, together with the values indicated by the flow monitor. Any drifting in the monitor readings could then be detected. These calibration checks were only possible on flow monitors constantly situated in a flow. Under dry weather conditions spill flow monitors are positioned in dry sewers. These monitors are only in a flow during storm events when the CSO spills. However, it was possible to assess whether any drifting of the spill flow monitor readings had occurred from an examination of the raw data after each site visit .

During the monitoring periods of both sites drifting of the depth readings occurred with the spill flow monitors. These monitors were removed from site, cleaned down, checked and calibrated prior to being reinstated. The monitors were tested in the Hydraulics Laboratory and a series of readings taken prior to calibration. These readings were noted along with the actual depth in the testing tank, taken manually with a metre rule. By plotting the actual depth readings against the flow monitor readings prior to calibration it was possible to translate the spill flow data readings from the flow monitor into actual depth readings. The other flow monitors were also removed from site and calibrated to ensure the data obtained was accurate. Fortunately, there were no rainstorm events during this period of calibration. In an attempt to alleviate this drifting problem, the flow monitors were removed and calibrated every three months.

Difficulties arose in the collection of gross solids when rainstorm events occurred in close succession making entry into the combined sewer overflow impossible on safety grounds. Consequently, several sets of gross solids analysed represent two or more rainstorm events. Multiple storms during weekends or bank holidays also presented a similar problem.

3.6.2 Sewage treatment works

The work carried out at Long Lane sewage treatment works was not rain dependent Consequently, daily site visits were made and a series of controlled tests performed on each screen. By opening two penstocks at the entrance and exit to the side channel the incoming flow was diverted through the inclined bar screen, figure 3.23. The penstocks on the main channel were closed to prevent flow entering the D-screen channel, thus isolating the inclined bar screen. The gross solids retained and subsequently raked onto the conveyor belt by the screen and the gross solids which passed through the screen were collected using the collection platform and the mesh frame, figures 3.24 and 3.25. Reversing the penstock arrangement diverted the inlet flow through the D-screen enabling gross solids retained and passed by this screen to be collected. At the start of each testing session the flow monitor was connected up to the transducer on site and set logging. Because data was only required during the testing sessions, the flow monitor was not left logging continuously. In order to maximise the amount of data obtained during testing, the flow monitor was programmed to record at 10 second intervals.

The transducer was checked, cleaned and de-ragged at the start of each testing session. Manual depth and velocity readings were taken during testing and compared with the flow monitor readings to check for any drifting of the measured depths, and to ensure the monitor was working correctly. It was found that no drifting of the depth readings occurred during the period of testing.

For each individual test, the screen under test was switched from automatic to manual so that the screen was raked continuously as is the mode of operation of CSO screens during storm events. The rectangular frame supporting the Copasac mesh was inserted between the steel guides into the downstream flow to collect any gross solids passing through the screen. Any gross solids already on the conveyor belt were allowed to fall into the skip before the platform was positioned over the skip to

Figure 3.23 Penstocks on Long Lane STW inlet

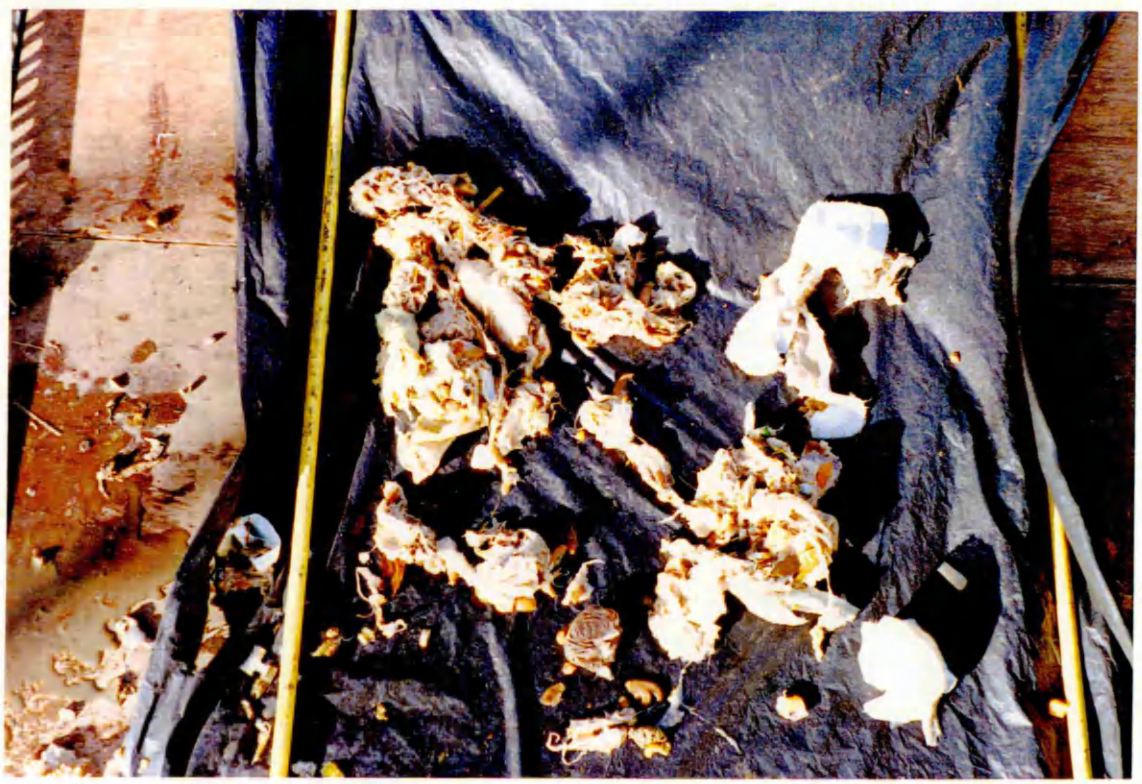


Figure 3.24 Gross solids retained by inclined bar screen at Long Lane STW

Figure 3.25 Gross solids passed by inclined bar screen at Long Lane STW

collect gross solids retained by the screen. After 5 minutes, the rectangular frame was removed from the downstream channel and drained. Once the rectangular frame had been removed the gross solids on the conveyor belt were allowed to drop onto the platform over the skip. The platform was then lifted off the skip. The gross solids collected each day were not taken back to the laboratory for analysis as this would have presented a health hazard in the laboratory because of the time required to analyse each individual sample and the difficulties in disposing of them hygienically. Initially, the material deposited on the collection platform was placed into a black bin liner and weighed using a set of kitchen scales. After draining the Copasac was placed into a black bin liner and weighed, again using a set of kitchen scales. The weights of the two samples were then adjusted to allow for the additional weight of the bin liners and the Copasac. Later in the testing programme the Copasac was weighed without a bin liner and only the Copasac weight was deducted from these samples. More detailed data was required on the composition of each sample so subsequent tests were carried out. Each sample was sorted, categorised and disposed of on site, and several sets of samples were photographed as a record of the different types of gross solids collected. Each individual material category was weighed separately using a set of kitchen scales. This procedure was repeated several times for both the inclined bar screen and the D-screen. The testing sessions were either carried out in the morning or in the afternoon and this was alternated to investigate whether the flow variation between morning and afternoon affected screen efficiency. Table 3.1 shows the weather conditions encountered during testing at Long Lane sewage treatment works.

Table 3.1 Testing Conditions for Long Lane STW

Date	Morning	Afternoon	Weather Conditions
20/9/93		*	heavy rain
21/9/93		*	fine
22/9/93		*	fine
23/9/93	*		fine
4/10/93		*	sunny
6/10/93	*		overcast
7/10/93		*	fine
14/10/93	*		fine, cold
15/10/93	*		fine, cold
18/10/93		*	sunny
19/10/93		*	sunny
21/10/93	*		fine, windy
25/10/93		*	overcast
26/10/93		*	overcast
27/10/93	*		overcast
28/10/93	*		overcast
1/11/93		*	overcast
2/11/93	*		overcast
3/11/93	*		fine, damp
4/11/93	*		fine, damp
8/11/93		*	overcast
9/11/93	*		drizzle
10/11/93	*		wet, cold

During testing on 7th October 1993, the storm water from the works storm tanks was being pumped back into the inlet flow. The increased volume of sewage from the storm tanks meant the length of each testing session had to be reduced due to the possibility of overspill to the river.

Testing at Long Lane sewage treatment works commenced later than anticipated due to mechanical failure of the inclined bar screen. The motor of this screen had a broken shear pin which rendered the screen inoperable. Yorkshire Water experienced difficulty in obtaining the parts required to repair the broken screen which resulted in delays to the testing programme. The repair work to this screen was finally carried out at the end of August 1993.

Once testing commenced, it was found that due to an ill-fitting penstock at the entrance to the channel of the D-screen, not all of the flow was being diverted through the inclined bar screens. Sandbags were inserted in front of the penstock to provide a seal with the bed of the channel and alleviate the problem.

Initially the transducer of the flow monitor was fixed to a U-band which was screwed to the side walls of the channel, however, it was not possible to fasten the band to the base of the channel. As a result of this the band kept being pulled off the base of the channel when debris snagged on it and severe ragging of the sensor head occurred, distorting the data readings. Consequently, the U-band was removed and an L-shaped frame manufactured to hold the transducer, this eliminated the lifting and significantly reduced the amount of ragging up.

A gap between the bottom of the inclined bar screen and the channel bed was found during testing, through which material could by-pass the screen. Blocking the gap seemed to be virtually impossible. However, 5 weeks into testing due to zero flow conditions a hinged plate was discovered attached to the base of the screen but lying

Figure 3.26 Hinged plate at base of inclined bar screen (Long Lane STW)

on the channel bed. Once lifted from the base of the channel the gap was totally sealed, figure 3.26.

Wet weather posed problems during testing and on particularly wet days testing had to be abandoned. The mesh frame used for collecting gross solids passing through the screens blinded quickly during testing, causing the incoming flow to back-up behind it. The increased volume of sewage entering the works on wet days meant the water level in the inlet channel rose up to the overflow height once the mesh frame was inserted downstream. Consequently, the length of each test had to be reduced to prevent overspill directly into the river. On very windy days the gross solids were blown off the conveyor belt or off the collection platform. This made it difficult to assess the actual amount of material being retained by the screens. On certain days testing had to be abandoned.

Draining of the gross solids retained on the Copasac mesh was found to be difficult. Several methods were tried, including standing the frame diagonally across the channel for a standard period of time and knocking the frame above the channel to try to shake off the excess liquid. In the end the samples were held over the channel to allow the excess water to run-off, the Copasac was then removed from the steel frame and manually squeezed/wrung out to drain off most of the remaining water.

3.7 Data Analysis

3.7.1 Combined sewer overflows

Site surveys had to be carried out because the drawings obtained from Design & Building Services were design drawings and not as-built drawings. Consequently, there were discrepancies between some of the dimensions given on the drawings and the actual site measurements. The actual overflow chamber, weir and pipe dimensions were measured on site. By finding the distances between manhole covers, obtaining their respective levels and taking depth measurements from cover to invert level, determination of the length and fall of the relevant pipes was possible. The data was then used to establish the extent of backing up in the sewerage system during an overflow event and to determine the storage in the chamber and the upstream pipes.

At low flows, when the inflow is equal to the continuation flow, there is a continuous relationship between depth and discharge. As the flow increases and the throttle pipe starts to control upstream depths, the continuation flow is related to the depth of water in the overflow chamber which determines the depth of flow in the inlet pipe. The continuity equation controls the relationship between the inlet depth and the continuation flow, i.e.

$$\text{Flow In} - \text{Flow Out} = \text{Rate of Change in Storage} \qquad (3.1)$$

According to Lonsdale et al, (1993) the change in storage in the time step n to n+1 is given in finite difference form by:

$$\left(Qin_n + Qin_{n+1}\right)\frac{dt}{2} - \left(Qout_n + Qout_{n+1}\right)\frac{dt}{2} = S_{n+1} - S_n \qquad (3.2)$$

where Q = flow rate

S = Storage Volume

dt = Time Step

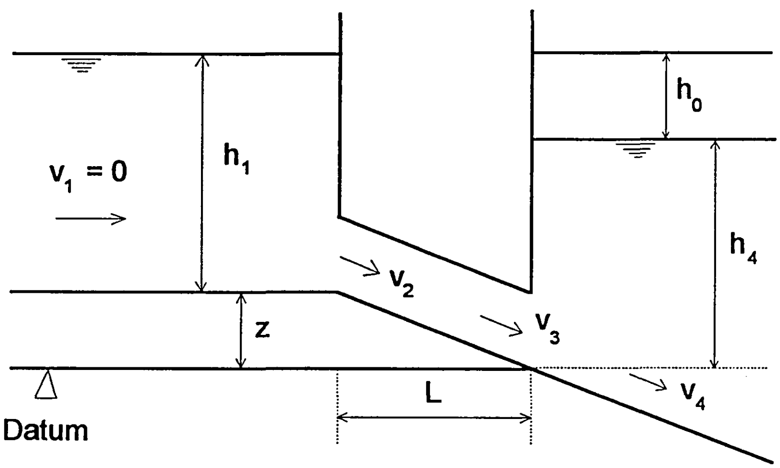
Where the continuation flow and spill flow are both measured, the values may be added together to give Qout at any time step. Any missing data in the inflow can then be calculated by rearranging Equation 3.2.

$$Qin_{n+1} = Qout_n + Qout_{n+1} + \left(S_{n+1} - S_n\right)\frac{2}{dt} - Qin_n \qquad (3.3)$$

Missing continuation flow values can be determined using data from the inflow monitor and storage volumes calculated from the inflow depth measurement.

$$Qout_{n+1} = Qin_n + Qin_{n+1} + (S_n - S_{n+1}) \frac{2}{dt} - Qout_n \qquad (3.4)$$

The continuation flow is a function of the differential head across the throttle pipe. As described by Lonsdale et al (1995), the results of the block-off test detailed in 3.6.1 can be used to relate the differential head across the throttle pipe to the continuation flow. The continuation flow at any time can be calculated from the known depths either side of the previous time step, the inflow and the storage in the chamber, using equation 3.1. In practice, the time-depth curve is generally not smooth and a theoretical curve is fitted based on an energy analysis of the flow (Lonsdale et al, 1995). The discharge through the throttle pipe is determined by applying the energy equation:



$$h_1 + \frac{v_1^2}{2g} + z = h_4 + \frac{v_4^2}{2g} + \text{losses} \qquad (3.5)$$

Losses are made up of an entry loss, $0.5v_2^2 / 2g$, a friction head loss, $\lambda l v_3^2 / 2gd$, and an exit loss, $(v_3 - v_4)^2 / 2g$.

A form of the Manning equation which relates λ directly to the roughness of the surface k is used to calculate the friction loss:

$$\lambda = 0.180k^{\frac{1}{3}} / d^{\frac{1}{3}} \qquad (3.6)$$

Where k = surface roughness (m)

d = pipe diameter (m)

In most cases v_1 is small compared to the other velocities. Where no throttle plate or penstock is fitted to the throttle pipe $v_2 = v_3$ and as a first approximation, v_4 is proportional to v_3 so that $v_4 = Cv_3$. Rearranging equation 3.5 gives:

$$Q = C_d A \sqrt{2gh_0} \qquad (3.7)$$

Where A = cross-sectional area of throttle pipe

h_0 = drop in hydraulic gradient across throttle pipe

C_d = coefficient of discharge, and is given by

$$C_d = \frac{1}{\sqrt{C^2 + (1-C)^2 + 0.5 + 0.180Lk^{\frac{1}{3}} / d^{\frac{4}{3}}}}$$

Values of C and k are found by producing the best fit curve from the blocking-off test data.

The following expression was used to obtain any missing data from the spill flow monitors:

$$Q = C_d \frac{2}{3}\sqrt{2g}\,BH^{\frac{3}{2}} \qquad (3.8)$$

Where C_d = coefficient of discharge

B = Breadth of weir

H = Head above weir crest

The large storage capacity of the upstream system of the Extended stilling pond overflow meant that a blocking-off test developed by Lonsdale et al (1995) was impractical because of the length of time required to fill and empty the overflow chamber. Consequently a calibration curve for the spill pipe was produced. This was done by plotting the values of discharge and depth for the spill pipe onto a log scale to produce a straight line relationship. The method of least squares was then used to find the line of best fit for the raw data. The equation of the straight line was then determined and translated back to a power law relationship between depth and discharge:

$$Q \propto D^{n} \qquad (3.9)$$

Where Q = Spill Discharge (m^3/sec)

D = Depth in Spill Pipe (m)

n = constant

$$Q = k D^{n} \qquad (3.10)$$

Where k = constant

Taking logs of both sides gives a straight line relationship (y = c + mx):

$$\log Q = \log k + n \log D \qquad (3.11)$$

The constants k and n are found by calculating the gradient of the line and the y-intercept.

Several rainstorm events had missing velocity readings for the spill flow, but the calibration curve enabled estimates to be made of these values, thus providing a set of complete data.

The efficiency of the screens was calculated for total gross solids and for individually classified materials, e.g. sanitary towels, paper towels, tampons, etc.. The efficiency definitions used were as follows:

$$\text{Efficiency of screen} = \frac{\text{mass of gross solids retained by screen}}{\text{total mass of gross solids presented to screen}} \times 100\ \% \qquad (3.12)$$

$$\begin{array}{l}\text{Efficiency of screen}\\ \text{for individual materials}\end{array} = \frac{\text{mass of material retained by screen}}{\text{total mass of that material presented to screen}} \times 100\ \% \qquad (3.13)$$

3.7.2 Sewage treatment works

Drawings were unavailable for Long Lane sewage treatment works so a full survey of the works inlet was carried out and a working drawing produced. Manual calibration checks were made during each site visit and the monitor was checked at the end of each testing period to ensure the data collected were reliable. The data were downloaded and transferred on to a personal computer in the same way as the CSO field data. The raw depth and velocity values were then loaded from SSAS into a spreadsheet to calculate the flowrates through the screens. The relationship between the depth readings and the velocity readings was plotted for several test days to check there was consistency in the data. The data chosen for these plots were randomly selected. For each individual test the mean flowrate through the screen was found. The efficiency definitions used for the combined sewer overflows were used to find the screen retention efficiencies of the two screens at the sewage treatment works.

3.8 Results of Analysis

3.8.1 Combined sewer overflows

The results of the blocking-off test at the Sharpe and Kirkbride stilling pond are shown graphically in figures 3.27 and 3.28. The spill pipe calibration curves produced for the Extended stilling pond are given in figures 3.29 to 3.30. The relationship between depth and discharge was found to be:

$$Q = 1.20\ D^{1.34} \qquad (3.14)$$

Where Q = Spill Discharge (m^3/sec)

D = Depth in Spill Pipe (m)

This equation was used to fill in any incomplete readings for the spill flow. The inflow for the Extended stilling pond was calculated using equation 3.3.

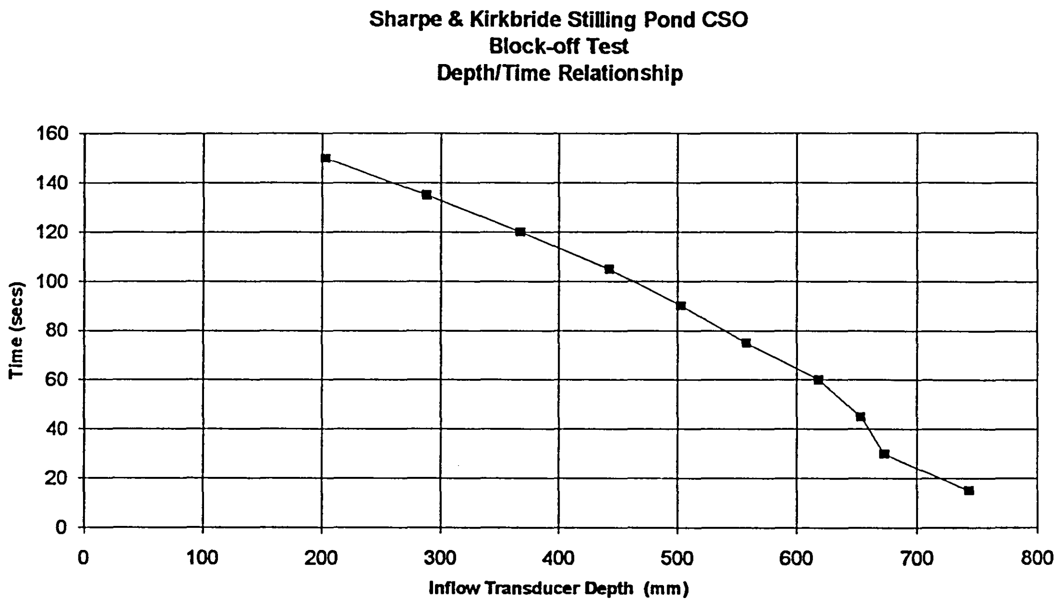


Figure 3.27 Depth/Time relationship for Sharpe & Kirkbride block-off test

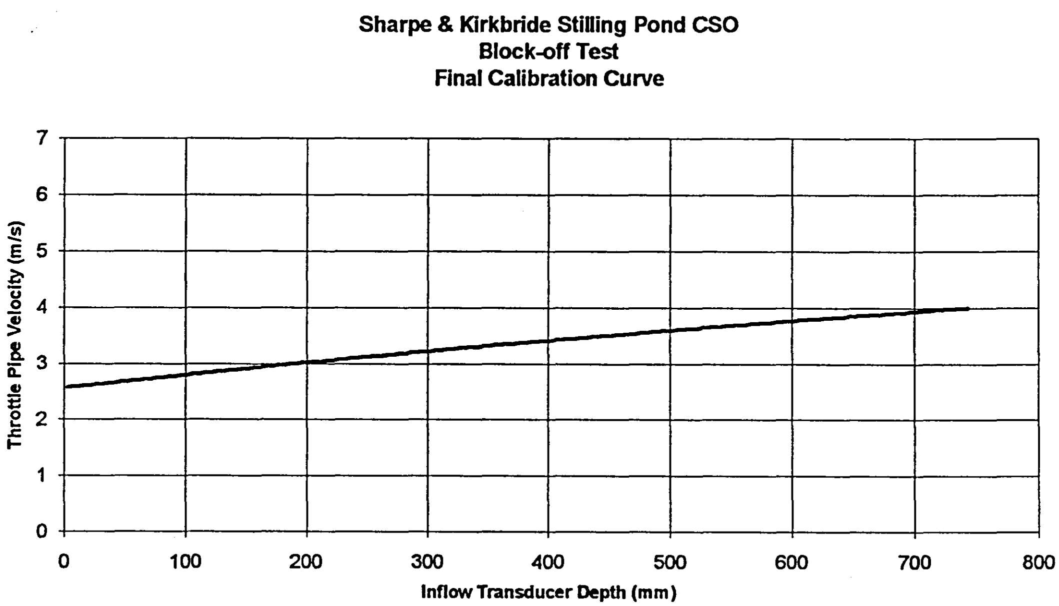


Figure 3.28 Final calibration curve for Sharpe & Kirkbride block-off test

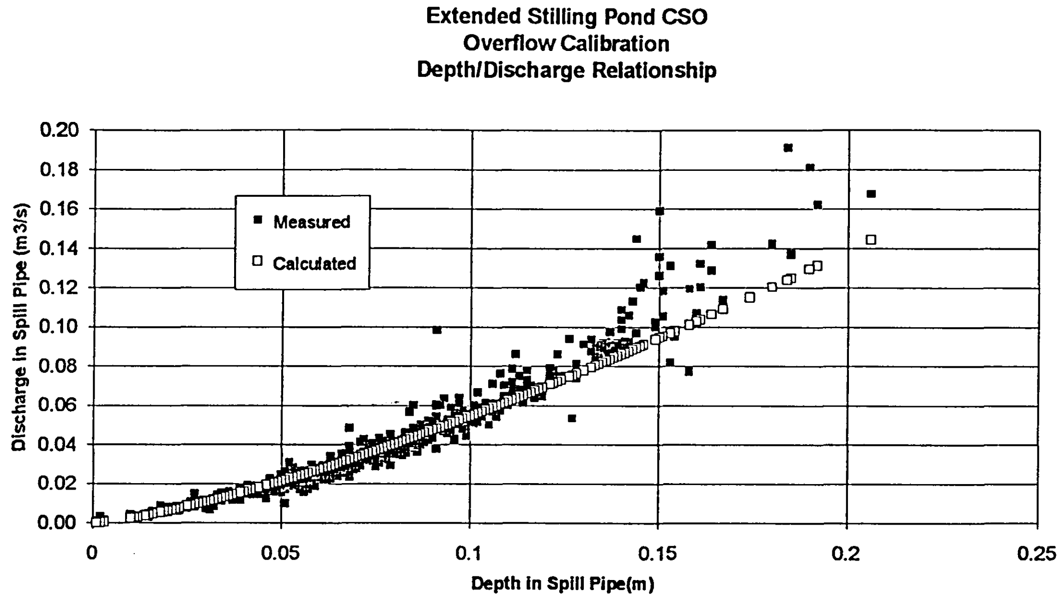


Figure 3.29 Depth/Discharge relationship for Extended Stilling Pond

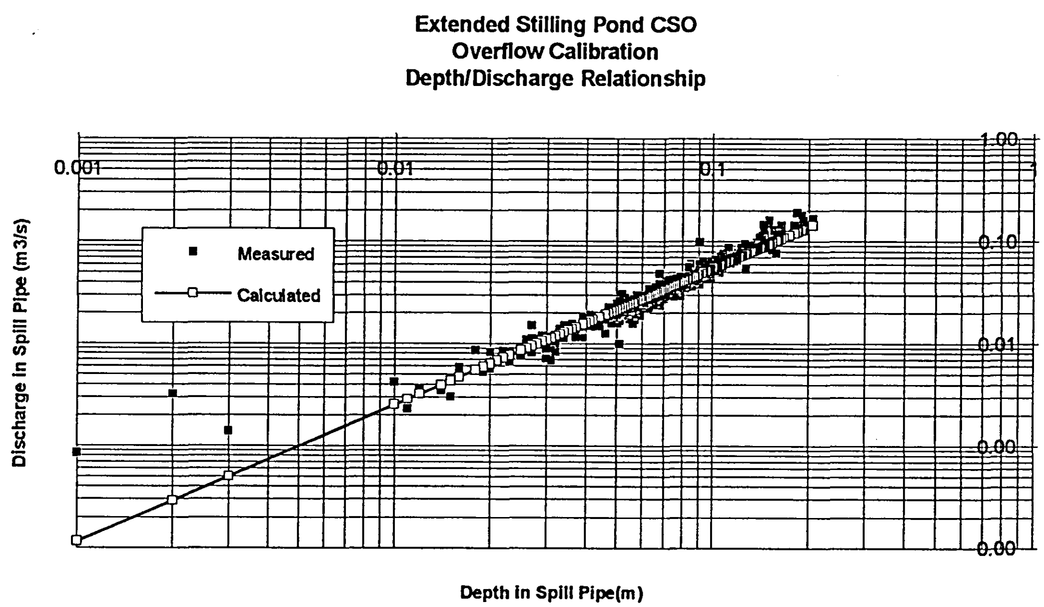


Figure 3.30 Log plot of Depth/Discharge relationship for Extended Stilling Pond

The gross solids collected after each significant storm event were brought back to Sheffield Hallam University in two separate bin liners for analysis in a fume cupboard in the public health laboratory. The gross solids retained by the screens were sorted with a pair of tongs into different materials in order to establish the sample composition. The sample was broken down into as many different materials as practically possible. However, some materials were grouped together, e.g. plastics, sweet wrappers and leaves. Initially sanitary products were grouped together. But since major complaints are received about the discharge of particular sanitary items it was decided to classify them individually, e.g. sanitary towels, tampons etc. Certain materials were difficult to identify they could only be grouped into materials of fat origin or materials of paper origin. Classification of gross solids which passed through the screens was more difficult. A large proportion of the material passing through the screen would blind the plastic mesh sack making it impossible to separate them from the sack. Certain solids could be peeled off the sacking for bagging and weighing but the material which adhered to the mesh had to be left and the sack weighed with the material still intact. The weight of the mesh sack was then deducted from the total weight to establish the net weight of this material. Because of the difficulties outlined above the following categories were finally chosen as being the most representative.

Condoms	Miscellaneous (Fat Origin)
Disposable Nappies	Paper Towels
Faeces	Plastic
Fine Tissue Paper	Sanitary Towels
Leaves	Sweet Wrappers
Miscellaneous (Paper Origin)	Tampons

Once divided into individually classified materials, each group was bagged and weighed and then disposed of.

A number of contributing factors were thought to influence screen retention efficiency these were:

The total mass of gross solids presented to the screen

The maximum flowrate through the screen

The volume of spill during each storm event

The duration of spill

On examination of the volume of spill and duration of spill for each storm event it was clear that these parameters needed to be represented together rather than separately to avoid producing misleading relationships. This was because a short duration storm event often had a similar volume of spill to one which resulted in spilling for several hours. An intensity of each overflow was defined using the two parameters:

$$\text{Mean Overflow Intensity} = \frac{\text{Total Volume Spilt during a particular storm event}}{\text{Duration of Spill}} \quad (m^3/\text{min}) \qquad (3.15)$$

These contributing factors were plotted against each other to investigate whether a relationship existed between any of them and to see if there were any obvious trends between the various parameters. Graphs were produced for each individual material which showed the individual material mass against the mean overflow intensity and the maximum flowrate in a bar chart form, figures 3.31 to 3.76. The mass retained on the screen and the mass passing through the screen were shown separately. Scatter graphs were also plotted for each individual material of screen retention efficiency against maximum flowrate, total mass of gross solids presented to the screen and mean overflow intensity, figures 3.77 to 3.121 The total mass of gross solids presented to the screen was plotted against the maximum flowrate through the screen and the mean overflow intensity, figures 3.122 to 3.157. **The work carried out in chapter 4 showed that the actual mean retention efficiency of the Copasac frames used to collect gross solids passed through the screens was 56%. When examining these graphs the screen retention efficiencies and the total mass presented to the screens should be factored by 0.56 to allow for the retention efficiency of the plastic mesh Copasacs used to measure their performance.**

Tables 3.2 and 3.4 show the classification of the individual materials and the percentage of each material retained and passed by the screens. The overall efficiency of the screen is given by the total at the bottom of the table. Also given in tables 3.2 and 3.4 are the individual material percentages of the total sample showing which gross solids are most commonly presented to the screens during a storm event. The samples are given in ascending order of mean overflow intensity (m^3/min). Tables 3.3 and 3.5 show the actual material mass of gross solids retained and passed through the screens again in ascending order of mean overflow intensity.

3.8.2 Sewage treatment works

Tables 3.6 and 3.7 show the mass of material retained by the screens and the mass passed by the screens. The retention efficiency of each screen is given with the corresponding flow rate and also the mean screen retention efficiency, mean flow rate and the total volume for each particular testing session. The overall mean screen retention efficiency is given at the beginning of each table. The screen retention efficiency for the inclined bar screen is also given before and after the gap at the base of the screen was sealed.

Sample classification was carried out on site during subsequent tests. The gross solids deposited on the collection platform on the skip were sorted using a pair of tongs and each individual category was bagged separately, weighed on a set of kitchen scales and then disposed of in the skip on the site. As much of the gross solids adhering to the Copasac mesh were removed, categorised and weighed before being returned to the site skip. The remaining material was weighed on the Copasac and the weight of the Copasac deducted from the mass. Tables 3.8 and 3.9 show the mass of individual materials retained and passed by each screen. Tables 3.10 and 3.11 show the classification of the individual materials and the percentage of each material retained and passed by each screen.

Graphs were plotted for screen retention efficiency against mean flowrate through the screen and gross solids presented to each screen, figures 3.158 to 3.177. The total gross solids mass presented to each screen was also plotted against the mean flowrate through the screen figures 3.178 to 3.192.

SAMPLE CLASSIFICATION - Sharpe Kirkbride Stilling Pond

Table 3.2

Efficiencies & Percentage of overall Sample Mass

Sample no.	8			5			6		
Sewage to river (m^3)	20.24			33.51			237.89		
Intensity of overflow (m^3/min)	0.98			1.08			1.39		
Sewage to treatment (m^3)	85.79			123.99			1202.53		
Overflow no.	30 & 31			18			19 & 20		
Material (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	4.8	100.0	0.0
Clear Plastic Wrappers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Clothes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Disposable Nappies	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Faeces	34.4	50.0	50.0	1.8	25.0	75.0	9.4	90.9	9.1
Fine Paper	4.9	37.5	62.5	51.9	3.0	97.0	57.8	5.9	94.1
Leaves	34.7	88.5	11.5	2.3	5.7	94.3	1.1	20.0	80.0
Misc.(Absorbant)	4.6	66.7	33.3	21.9	0.0	100.0	1.3	100.0	0.0
Misc.(Non-absorbant)	2.8	55.6	44.4	0.0	0.0	0.0	1.3	0.0	100.0
Paper Towels	0.0	0.0	0.0	1.8	50.0	50.0	3.1	45.2	54.8
Sanitary Towels	11.7	63.2	36.8	14.9	73.5	26.5	16.3	78.9	21.1
Sweet Wrappers	7.1	60.9	39.1	1.8	25.0	75.0	1.3	66.7	33.3
Tampons	0.0	0.0	0.0	3.7	100.0	0.0	3.6	100.0	0.0
TOTAL	100.0	66.0	34.0	100.0	18.1	81.9	100.0	37.0	63.0

SAMPLE CLASSIFICATION - Sharpe Kirkbride Stilling Pond

Table 3.2 (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	1			7			4		
Sewage to river (m^3)	17.46			102.11			172.1		
Intensity of overflow (m^3/min)	1.46			1.57			2.47		
Sewage to treatment (m^3)	153.92			412.33			445.66		
Overflow no.	3			21,22,23 & 24			16 & 17		
Material (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	2.1	100.0	0.0
Clear Plastic Wrappers	0.0	0.0	0.0	0.0	0.0	0.0	0.5	100.0	0.0
Clothes	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	100.0
Disposable Nappies	0.0	0.0	0.0	0.0	0.0	0.0	3.4	78.9	21.1
Faeces	1.5	57.7	42.3	6.5	96.8	3.2	12.6	97.1	2.9
Fine Paper	58.0	7.1	92.9	72.0	12.5	87.5	48.4	10.9	89.1
Leaves	4.1	25.3	74.7	0.4	0.0	100.0	1.6	66.7	33.3
Misc.(Absorbant)	7.0	38.2	61.8	0.0	0.0	0.0	4.3	100.0	0.0
Misc.(Non-absorbant)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Paper Towels	12.4	68.6	31.4	6.2	81.6	18.4	4.3	87.5	12.5
Sanitary Towels	11.8	72.4	27.6	13.0	84.8	15.2	21.6	68.3	31.7
Sweet Wrappers	5.3	73.1	26.9	1.9	66.7	33.3	1.1	66.7	33.3
Tampons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	29.6	70.4	100.0	32.7	67.3	100.0	47.5	52.5

SAMPLE CLASSIFICATION - Sharpe Kirkbride Stilling Pond

Table 3.2 (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	10			3	9			2
Sewage to river (m^3)	205.08			1961	442.66			509
Intensity of overflow (m^3/min)	3.42			4.09	4.99			5.28
Sewage to treatment (m^3)	409.35			5729.35	471.58			540.654
Overflow no.	35				33 & 34			
Material (grams)	% sample	Retained	Passing	N/A	% sample	Retained	Passing	N/A
Condoms	0.0	0.0	0.0	Note: Frame Destroyed during storm	0.0	0.0	0.0	Note: Frame Destroyed during storm
Clear Plastic Wrappers	0.4	72.7	27.3		1.2	100.0	0.0	
Clothes	0.1	0.0	100.0		0.1	0.0	100.0	
Disposable Nappies	0.8	100.0	0.0		2.3	100.0	0.0	
Faeces	5.3	100.0	0.0		4.9	100.0	0.0	
Fine Paper	27.1	14.8	85.2		51.1	10.3	89.7	
Leaves	38.5	15.5	84.5		17.0	30.7	69.3	
Misc.(Absorbant)	0.0	0.0	0.0		1.1	91.9	8.1	
Misc.(Non-absorbant)	0.0	0.0	0.0		0.0	0.0	0.0	
Paper Towels	11.1	23.6	76.4		2.9	39.4	60.6	
Sanitary Towels	12.7	77.6	22.4		13.8	71.2	28.8	
Sweet Wrappers	1.6	65.0	35.0		3.2	80.3	19.7	
Tampons	2.3	50.0	50.0		2.4	80.0	20.0	
TOTAL	100.0	31.0	69.0		100.0	35.3	64.7	

SAMPLE CLASSIFICATION - Sharpe Kirkbride Stilling Pond

Table 3.3

Sample Mass (Grams)

Sample no.	8		5		6		1		7	
Sewage to river (m^3)	20.24		33.51		237.89		17.46		102.11	
Intensity of overflow (m^3/min)	0.98		1.08		1.39		1.46		1.57	
Sewage to treatment (m^3)	85.79		123.99		1202.53		153.92		412.33	
Overflow no.	30 & 31		18		19 & 20		3		21,22,23 & 24	
Material (grams)	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill
Condoms	0	0	0	0	0	0	0	0	0	0
Clear Plastic Wrappers	0	0	0	0	0	0	0	0	0	0
Clothes	0	0	0	0	113	0	0	0	0	0
Disposable Nappies	0	0	0	0	0	0	0	0	0	0
Faeces	56	56	10	30	200	20	15	11	150	5
Fine Paper	6	10	35	1150	80	1270	73	950.5	215	1500
Leaves	100	13	3	50	5	20	18.3	54	0	10
Misc.(Absorbant)	10	5	0	500	30	0	47	76	0	0
Misc.(Non-absorbant)	5	4	0	0	0	30	0	0	0	0
Paper Towels	0	0	20	20	33	40	150	68.5	120	27
Sanitary Towels	24	14	250	90	300	80	150.5	57.5	263	47
Sweet Wrappers	14	9	10	30	20	10	68	25	30	15
Tampons	0	0	84	0	84	0	0	0	0	0
TOTAL	215	111	412	1870	865	1470	521.8	1242.5	778	1604

SAMPLE CLASSIFICATION - Sharpe Kirkbride Stilling Pond

Table 3.3 (Continued)

Sample Mass (Grams)

Sample no.	4		10		3		9		2	
Sewage to river (m^3)	172.1		205.08		1961		442.66		509	
Intensity of overflow (m^3/min)	2.47		3.42		4.09		4.99		5.28	
Sewage to treatment (m^3)	445.66		409.35		5729.35		471.58		540.654	
Overflow no.	16 & 17		35		10,11,12,13,14 & 15		33 & 34		4,5,6,7 & 8	
Material (grams)	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill
Condoms	0	3	0	3	9	Note: Frame destroyed during storm	0	6	0	Note: Frame destroyed during storm
Clear Plastic Wrappers	30	0	8	3	100		71	0	150	
Clothes	115	0	0	0	620		0	0	320	
Disposable Nappies	150	40	19	0	222		132	0	200	
Faeces	680	20	129	0	270		279	0	1140	
Fine Paper	295	2400	98	566	1000		301	2626	1115	
Leaves	60	30	146	798	260		299	676	340	
Misc.(Absorbant)	240	0	0	0	200		57	5	1350	
Misc.(Non-absorbant)	0	0	0	0	0		0	0	0	
Paper Towels	210	30	64	207	200		65	100	420	
Sanitary Towels	820	380	242	70	950		562	227	2000	
Sweet Wrappers	40	20	26	14	180		147	36	295	
Tampons	0	0	28	28	0		112	28	0	
TOTAL	2640	2923	760	1689	4011	0	2025	3704	7330	0

SAMPLE CLASSIFICATION - Extended Stilling Pond CSO

Table 3.4

Efficiencies & Percentage of overall Sample Mass

Sample no.	5			3			1		
Sewage to river (m^3)	6.94			95.52			122.04		
Intensity of overflow (m^3/min)	0.631			1.327			1.649		
Sewage to treatment (m^3)	147.46			476.67			no data		
Overflow no.	11			7			2		
Material (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clear Plastic Wrappers	0.0	0.0	0.0	0.0	0.0	0.0	0.6	100.0	0.0
Faeces	4.2	100.0	0.0	1.7	100.0	0.0	5.8	100.0	0.0
Fine Paper	44.5	0.0	100.0	33.7	0.0	100.0	19.4	0.0	100.0
Leaves	44.6	0.0	100.0	40.0	15.5	85.5	42.8	40.7	59.3
Misc.(Absorbant)	0.0	0.0	0.0	1.0	100.0	0.0	0.0	0.0	0.0
Paper Towels	0.0	0.0	0.0	8.3	100.0	0.0	1.0	100.0	0.0
Sanitary Towels	0.0	0.0	0.0	0.4	100.0	0.0	0.7	100.0	0.0
Sweet Wrappers	6.7	86.0	14.0	10.7	75.0	25.0	27.8	97.2	2.8
Tampons	0.0	0.0	0.0	4.2	100.0	0.0	0.8	100.0	0.0
Tea Bags	0.0	0.0	0.0	0.0	0.0	0.0	1.1	100.0	0.0
TOTAL	100.0	9.9	90.1	100.0	29.8	70.2	100.0	54.5	45.5

SAMPLE CLASSIFICATION - Extended Stilling Pond CSO

Table 3.4 (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	2			4		
Sewage to river (m^3)	123.65			114.98		
Intensity of overflow (m^3/min)	2.188			2.395		
Sewage to treatment (m^3)	683.23			no data		
Overflow no.	3,4,5			9		
Material (grams)	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0
Clear Plastic Wrappers	0.3	100.0	0.0	0.0	0.0	0.0
Faeces	3.6	100.0	0.0	4.4	100.0	0.0
Fine Paper	23.3	0.0	100.0	37.0	0.0	100.0
Leaves	44.9	30.4	69.6	46.5	20.3	79.7
Misc.(Absorbant)	3.2	100.0	0.0	0.0	0.0	0.0
Paper Towels	5.9	100.0	0.0	4.3	100.0	0.0
Sanitary Towels	0.7	100.0	0.0	1.0	100.0	0.0
Sweet Wrappers	12.2	93.8	6.3	6.8	100.0	0.0
Tampons	5.9	92.9	7.1	0.0	0.0	0.0
Tea Bags	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	100.0	44.2	55.8	100.0	25.9	74.1

SAMPLE CLASSIFICATION - Extended Stilling Pond CSO

Table 3.5

Sample Mass (Grams)

Sample no.	5		3		1		2		4	
Sewage to river (m^3)	33.75		95.52		122.04		123.65		114.98	
Intensity of overflow (m^3/min)	0.631		1.327		1.649		2.188		2.395	
Sewage to treatment (m^3)	147.46		476.67		no data		683.23		no data	
Overflow no.	11		7		2		3,4,5		9	
Material (grams)	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill	Screen	Spill
Condoms	0	0	0	0	0	0	0	0	0	0
Clear Plastic Wrappers	0	0	0	0	26	0	10	0	0	0
Faeces	31	0	14	0	235	0	138	0	171	0
Fine Paper	0	332	0	276	0	784	0	890	0	1455
Leaves	0	332	51	277	706	1028	521	1192	371	1455
Misc.(Absorbant)	0	0	8	0	0	0	121	0	0	0
Paper Towels	0	0	68	0	40	0	226	0	168	0
Sanitary Towels	43	7	66	22	1093	31	435	29	265	0
Sweet Wrappers	0	0	3	0	30	0	27	0	40	0
Tampons	0	0	34	0	34	0	208	16	0	0
Tea Bags	0	0	0	0	43	0	0	0	0	0
TOTAL	74	671	244	575	2207	1843	1686	2127	1015	2910

Long Lane Sewage Treatment Works

Table 3.6 - Inclined Bar Screen

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Volume (m^3)
20/9/93	9	1500	1700	1400	1650	3050	45.90	0.0558	3.35			
	9	1000	1700	900	1650	2550	35.29	0.0563	3.38			
	9	1000	1000	900	950	1850	48.65	0.0671	4.03	43.281	3.48	189.287
21/9/93	5	1300	1000	1200	950	2150	55.81	0.0539	3.23			
	5	1000	1100	900	1050	1950	46.15	0.0499	3.00			
	5	1300	1600	1200	1550	2750	43.64	0.0733	4.40	48.535	3.42	151.679
22/9/93	5	250	1400	150	1350	1500	10.00	0.0483	2.90			
	5	100	1400	0	1350	1350	0.00	0.0627	3.76			
	5	200	750	100	700	800	12.50	0.0538	3.23			
	5	300	1400	200	1350	1550	12.90	0.0727	4.36	8.851	3.42	152.579
23/9/93	5	600	1500	500	1450	1950	25.64	0.0651	3.90			
	5	1000	1400	900	1350	2250	40.00	0.0759	4.55			
	5	500	1300	400	1250	1650	24.24	0.0714	4.28			
	5	750	1500	650	1450	2100	30.95	0.0710	4.26	30.209	4.32	203.002
4/10/93	5	450	1600	350	1450	1800	19.44	0.1259	7.55			
	5	100	1000	0	850	850	0.00	0.0643	3.86			
	5	400	700	300	550	850	35.29	0.0800	4.80			
	5	200	1400	100	1250	1350	7.41	0.0820	4.92	15.536	5.1	250.352
6/10/93	5	700	1800	600	1650	2250	26.67	0.1097	6.58			
	5	600	1950	500	1800	2300	21.74	0.0853	5.12			
	5	750	1450	650	1300	1950	33.33	0.1122	6.73	27.246	5.94	164.813
7/10/93	4	150	700	50	550	600	8.33	0.1370	8.22			
	1.5	100	950	0	800	800	0.00	0.1448	8.69			

Table 3.6 - Inclined Bar Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Volume (m^3)
	5	350	1200	250	1050	1300	19.23	0.1896	11.38			
	5	300	1000	200	850	1050	19.05	0.1534	9.20	11.653	9	433.6
14/10/93	5	800	1800	700	1650	2350	29.79	0.1545	9.27			
	3	600	1800	500	1650	2150	23.26	0.1000	6.00			
	3	450	1400	350	1250	1600	21.88	0.1101	6.60			
	4.25	750	1550	650	1400	2050	31.71	0.1114	6.68			
	1.5	350	1200	250	1050	1300	19.23	0.1210	7.26	25.171	6.84	410.655
15/10/93	5	550	550	450	400	850	52.94	0.0865	5.19			
	4.5	400	800	300	650	950	31.58	0.0907	5.44			
	5	500	800	400	650	1050	38.10	0.0801	4.81			
	5	500	700	400	550	950	42.11	0.0977	5.86	41.180	5.16	218.576
18/10/93	5	50	350	0	200	200	0.000	0.0641	3.84			
	5	200	450	100	300	400	25.000	0.0404	2.43			
	5	150	500	50	350	400	12.500	0.0413	2.48			
	5	500	1100	400	950	1350	29.630	0.0546	3.28			
	5	100	400	0	250	250	0.000	0.0532	3.19	13.426	2.88	169.05
19/10/93	5	200	550	100	400	500	20.000	0.0662	3.97			
	5	500	550	400	400	800	50.000	0.0417	2.50			
	5	250	450	150	300	450	33.333	0.0688	4.13			
	5	200	550	100	400	500	20.000	0.0532	3.19			
	5	250	500	150	350	500	30.000	0.0542	3.25	30.667	3.24	178.029
21/10/93	5	1000	1100	900	950	1850	48.649	0.1012	6.07			
	5	600	1000	500	850	1350	37.037	0.0648	3.89			

Long Lane Sewage Treatment Works

Table 3.6 - Inclined Bar Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Volume (m^3)
	5	750	900	650	750	1400	46.429	0.0873	5.24			
	5	500	1000	400	850	1250	32.000	0.0686	4.11			
	5	900	1000	800	850	1650	48.485	0.0862	5.17	42.520	4.68	259.105
25/10/93	5	200	650	100	500	600	16.667	0.0635	3.81			
	5	450	800	350	650	1000	35.000	0.0475	2.85			
	5	500	800	400	650	1050	38.095	0.0458	2.75			
	5	600	900	500	750	1250	40.000	0.0566	3.40			
	5	250	500	150	350	500	30.000	0.0431	2.59	31.952	2.94	127.338
26/10/93	5	300	600	200	450	650	30.769	0.0466	2.79			
	5	700	1100	600	950	1550	38.710	0.0509	3.06			
	5	150	300	50	150	200	25.000	0.0420	2.52			
	5	600	800	500	650	1150	43.478	0.0487	2.92	34.489	2.7	95.743
27/10/93	5	300	900	200	750	950	21.053	0.0614	3.68			
	4.25	300	800	200	650	850	23.529	0.0867	5.20			
	5	600	900	500	750	1250	40.000	0.0506	3.03			
	4.5	400	900	300	750	1050	28.571	0.0877	5.26			
	5	550	1100	450	950	1400	32.143	0.0946	5.68	29.059	4.92	193.749
Hinged plate at base of screen lifted to block off gap at base of screen												
28/10/93	5	950	700	850	650	1500	56.667	0.0734	4.40			
	5	650	600	550	550	1100	50.000	0.0717	4.30			
	5	900	900	800	850	1650	48.485	0.0906	5.44			
	5	700	750	600	700	1300	46.154	0.0551	3.31			
	5	950	800	850	750	1600	53.125	0.0980	5.88	50.886	4.38	178.676

Long Lane Sewage Treatment Works

Table 3.6 - Inclined Bar Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Volume (m^3)
1/11/93	5	2000	700	1900	650	2550	74.510	0.0305	1.83			
	5	1700	550	1600	500	2100	76.190	0.0389	2.33			
	5	950	950	850	900	1750	48.571	0.0369	2.21			
	5	1150	500	1050	450	1500	70.000	0.0536	3.22			
	5	1300	450	1200	400	1600	75.000	0.0404	2.42	68.854	2.34	94.672
2/11/93	5	1450	750	1350	700	2050	65.854	0.0515	3.09			
	5	1350	800	1250	750	2000	62.500	0.0596	3.58			
	5	1100	800	1000	750	1750	57.143	0.0665	3.99			
	5	1050	800	950	750	1700	55.882	0.0500	3.00			
	5	1000	800	900	750	1650	54.545	0.0553	3.32	59.185	3.48	145.556
3/11/93	5	1000	500	900	450	1350	66.667	0.0642	3.85			
	5	550	450	450	400	850	52.941	0.0610	3.66			
	5	1200	850	1100	800	1900	57.895	0.1099	6.59			
	5	650	400	550	350	900	61.111	0.0560	3.36			
	5	200	300	100	250	350	28.571	0.0504	3.02	53.437	3.96	151.09
4/11/93	5	2150	850	2050	800	2850	71.930	0.0357	2.14			
	5	1200	850	1100	800	1900	57.895	0.0688	4.13			
	5	1400	650	1300	600	1900	68.421	0.0718	4.31			
	5	1100	800	1000	750	1750	57.143	0.0933	5.60			
	5	1000	650	900	600	1500	60.000	0.0561	3.36	63.078	3.78	151.805
8/11/93	5	1100	300	1000	250	1250	80.000	0.0344	2.07			
	5	400	700	300	650	950	31.579	0.0411	2.46			
	5	800	450	700	400	1100	63.636	0.0673	4.04			

Long Lane Sewage Treatment Works

Table 3.6 - Inclined Bar Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Volume (m^3)
	5	800	600	700	550	1250	56.000	0.0463	2.78			
	5	800	400	700	350	1050	66.667	0.0506	3.03	59.576	2.88	119.828
9/11/93	5	450	350	350	300	650	53.846	0.0424	2.54			
	5	200	300	100	250	350	28.571	0.0318	1.91			
	5	100	200	0	150	150	0.000	0.0540	3.24			
	5	400	400	300	350	650	46.154	0.0422	2.53			
	5	250	250	150	200	350	42.857	0.0444	2.66	34.286	2.4	138.94
10/11/93	5	1250	700	1150	650	1800	63.889	0.0266	1.60			
	5	900	400	800	350	1150	69.565	0.0684	4.11			
	5	1000	500	900	450	1350	66.667	0.0648	3.89			
	5	150	200	50	150	200	25.000	0.0459	2.75			
	5	1000	800	900	750	1650	54.545	0.0646	3.88	55.933	3.18	147.531

Long Lane Sewage Treatment Works

Table 3.7 - D-Screen

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Total Volume (m^3)
20/9/93	9	4100	2500	4000	2450	6450	62.02	0.0537	3.22			
	7	8100	2500	8000	2450	10450	76.56	0.0756	4.54	69.285	3.84	210.531
21/9/93	5	300	1500	200	1450	1650	12.12	0.0587	3.52			
	5	700	500	600	450	1050	57.14	0.0694	4.16			
	5	300	800	200	750	950	21.05	0.0580	3.48	30.106	3.42	155.281
22/9/93	5	50	400	0	350	350	0.00	0.0354	2.12			
	5	200	900	0	850	850	0.00	0.0759	4.55			
	5	200	1300	100	1250	1350	7.41	0.0642	3.85			
	5	50	700	0	650	650	0.00	0.0805	4.83	1.852	3.54	157.279
23/9/93	5	100	1000	0	950	950	0.00	0.0778	4.67			
	5	50	750	0	700	700	0.00	0.0765	4.59			
	5	500	2000	400	1950	2350	17.02	0.0584	3.51			
	5	400	1400	300	1350	1650	18.18	0.0733	4.40	8.801	4.38	213.886
4/10/93	5	200	850	100	700	800	12.50	0.0547	3.28			
	5	200	1300	100	1150	1250	8.00	0.0615	3.69			
	5	100	1400	0	1250	1250	0.00	0.0702	4.21			
	5	100	1700	0	1550	1550	0.00	0.0756	4.54	5.125	3.78	184.195
6/10/93	3.5	200	1700	100	1550	1650	6.06	0.0788	4.73			
	3.5	200	1400	100	1250	1350	7.41	0.1174	7.04			
	3.5	300	1100	200	950	1150	17.39	0.0819	4.92	10.286	5.64	155.255
7/10/93	5	200	1100	100	950	1050	9.52	0.1142	6.85			
	5	150	1000	50	850	900	5.56	0.1307	7.84			
	5	100	700	0	550	550	0.00	0.1282	7.69			

Long Lane Sewage Treatment Works

Table 3.7 - D-Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Total Volume (m^3)
	5	150	1000	50	850	900	5.56	0.1343	8.06	5.159	7.32	351.599
14/10/93	4	850	1600	750	1450	2200	34.09	0.1074	6.44			
	4.75	500	1600	400	1450	1850	21.62	0.0852	5.11			
	5	300	1200	200	1050	1250	16.00	0.0907	5.44			
	5	50	1100	0	950	950	0.00	0.0982	5.89			
	5	150	900	50	750	800	6.25	0.1243	7.46	15.593	5.64	338.38
15/10/93	5	300	850	200	700	900	22.22	0.0572	3.43			
	5.25	400	1550	300	1400	1700	17.65	0.0811	4.87			
	5	350	800	250	650	900	27.78	0.0624	3.75			
	5	250	650	150	500	650	23.08	0.0913	5.48	22.681	4.14	175.844
18/10/93	5	0	250	0	100	100	0.00	0.0593	3.56			
	5	100	600	0	450	450	0.00	0.0411	2.47			
	5	100	200	0	50	50	0.00	0.0386	2.32			
	5	0	350	0	200	200	0.00	0.0674	4.04			
	5	200	800	100	650	750	13.33	0.0419	2.52	2.667	2.880	166.991
19/10/93	5	200	400	100	250	350	28.57	0.0743	4.46			
	5	150	500	50	350	400	12.50	0.0463	2.78			
	5	750	1000	650	850	1500	43.33	0.0640	3.84			
	5	100	450	0	300	300	0.00	0.0571	3.42			
	5	100	400	0	250	250	0.00	0.0525	3.15	16.881	3.360	183.832
21/10/93	5	500	1300	400	1150	1550	25.81	0.0657	3.94			
	5	400	900	300	750	1050	28.57	0.0679	4.07			
	5	250	1000	150	850	1000	15.00	0.0846	5.07			

Long Lane Sewage Treatment Works

Table 3.7 - D-Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Total Volume (m^3)
	5	300	1100	200	950	1150	17.39	0.0665	3.99			
	5	200	900	100	750	850	11.76	0.0699	4.19	19.707	4.020	225.326
25/10/93	5	200	800	100	650	750	13.33	0.0820	4.92			
	5	150	400	50	250	300	16.67	0.0369	2.21			
	5	100	800	0	650	650	0.00	0.0327	1.96			
	5	100	400	0	250	250	0.00	0.0690	4.14			
	5	200	700	100	550	650	15.38	0.0470	2.82	9.077	3.000	128.860
26/10/93	5	150	400	50	250	300	16.67	0.0761	4.57			
	5	400	1350	300	1200	1500	20.00	0.0322	1.93			
	5	200	400	100	250	350	28.57	0.0662	3.97			
	5	200	1200	100	1050	1150	8.70	0.0383	2.30	18.483	3.000	105.982
27/10/93	5	300	1100	200	950	1150	17.39	0.0405	2.43			
	5	300	1300	200	1150	1350	14.81	0.0652	3.91			
	5	600	1350	500	1200	1700	29.41	0.0559	3.35			
	5	350	950	250	800	1050	23.81	0.0545	3.27			
	5	400	500	300	350	650	46.15	0.0365	2.19	26.316	3.420	133.843
28/10/93	5	250	850	150	800	950	15.79	0.0613	3.68			
	5	200	850	100	800	900	11.11	0.0752	4.51			
	5	350	950	250	900	1150	21.74	0.0874	5.25			
	5	400	650	300	600	900	33.33	0.0840	5.04			
	1.25	300	800	200	750	950	21.05	0.0453	2.72	20.605	4.080	166.208
1/11/93	5	200	400	300	350	650	46.15	0.0764	4.59			
	5	450	350	250	300	550	45.45	0.0356	2.14			

Long Lane Sewage Treatment Works

Table 3.7 - D-Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Total Volume (m^3)
	5	200	600	500	550	1050	47.62	0.0360	2.16			
	5	300	800	700	750	1450	48.28	0.0505	3.03			
	5	350	450	350	400	750	46.67	0.0423	2.54	46.834	2.760	113.866
2/11/93	5	150	800	50	750	800	6.25	0.0869	5.21			
	5	100	850	0	800	800	0.00	0.0520	3.12			
	5	200	900	100	850	950	10.53	0.0715	4.29			
	5	300	700	200	650	850	23.53	0.0385	2.31			
	5	150	800	50	750	800	6.25	0.0617	3.70	9.311	3.600	148.875
3/11/93	5	200	400	100	350	450	22.22	0.0769	4.62			
	5	400	700	300	650	950	31.58	0.0608	3.65			
	5	200	700	100	650	750	13.33	0.0354	2.13			
	5	150	1000	50	950	1000	5.00	0.0875	5.25			
	5	250	600	150	550	700	21.43	0.0417	2.50	18.713	3.480	134.564
4/11/93	5	300	700	200	650	850	23.53	0.0672	4.03			
	5	200	700	100	650	750	13.33	0.0774	4.65			
	5	100	500	0	450	450	0.00	0.0465	2.79			
	5	200	500	100	450	550	18.18	0.0641	3.84			
	5	200	1100	100	1050	1150	8.70	0.0738	4.43	12.748	3.780	151.271
8/11/93	5	500	1000	400	950	1350	29.63	0.0422	2.53			
	5	150	400	50	350	400	12.50	0.0913	5.48			
	5	300	1000	200	950	1150	17.39	0.0310	1.86			
	5	150	400	50	350	400	12.50	0.0547	3.28			
	5	200	550	100	500	600	16.67	0.0490	2.94	17.738	3.060	128.348

Long Lane Sewage Treatment Works

Table 3.7 - D-Screen (Continued)

Date	Time (mins)	Retained (grams)	Passed (grams)	Adjusted Retained (grams)	Adjusted Passed (grams)	Adjusted Total (grams)	Efficiency (%)	Flow (m^3/s)	Flow (m^3/min)	Average Efficiency (%)	Average Flow (m^3/min)	Total Volume (m^3)
10/11/93	5	300	550	200	500	700	28.57	0.0567	3.40			
	5	0	200	0	150	150	0.00	0.0317	1.90	14.286	2.460	46.236

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.8 - Inclined Bar Screen — Sample Mass (Grams)

Sample no.	1		2		3		1		2	
Date & Time	24/5/94	10.33am	24/5/94	10.45am	24/5/94	10.54am	25/5/94	10.04am	25/5/94	10.12am
Flow (m^3/min)	4.320		6.948		7.295		3.536		4.645	
Volume (m^3)	25.922		41.689		43.771		21.213		27.872	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.65	0.00
Cotton Bud Sticks	1.15	0.00	6.96	0.00	0.00	0.00	0.00	0.00	8.85	0.00
Cloth	31.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	626.35	0.00	439.52	0.00	175.35	0.00	244.15	0.00	163.20	0.00
F Paper, Veg & Faeces	416.30	1354.00	374.33	1086.37	272.25	1119.70	263.90	526.50	319.30	862.32
Paper towels	0.00	0.00	69.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	94.15	0.00	23.82	8.92	45.20	0.00	144.02	0.00	127.22	12.40
Tampons	106.27	0.00	26.45	0.00	43.00	0.00	105.75	0.00	163.25	0.00
TOTAL	1275.37	1354.00	940.08	1095.29	535.80	1119.70	757.82	526.50	787.47	874.72

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.8 - Inclined Bar Screen (Continued) Sample Mass (Grams)

Sample no.	3		4		5		6		1	
Date & Time	25/5/94	10.20am	1/6/94	10.53am	1/6/94	11.01am	1/6/94	11.08am	2/6/94	10.41am
Flow (m^3/min)	6.253		3.841		2.976		5.431		6.202	
Volume (m^3)	37.518		23.045		17.856		32.589		37.210	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton Bud Sticks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.36	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	54.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	118.15	972.55	155.90	688.15	1238.50	798.95	961.15	1032.20	495.80	582.10
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	163.05	14.40	17.50	0.00	167.35	0.00	253.10	0.00	113.95	0.00
Tampons	128.85	0.00	0.00	0.00	47.58	0.00	254.80	0.00	145.00	0.00
TOTAL	464.10	986.95	173.40	688.15	1453.43	798.95	1469.05	1032.20	761.11	582.10

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.8 - Inclined Bar Screen (Continued) Sample Mass (Grams)

Sample no.	2		3		1		2		3	
Date & Time	2/6/94	10.50am	2/6/94	10.59am	6/6/94	10.12am	6/6/94	10.19am	6/6/94	10.26am
Flow (m^3/min)	7.320		6.431		4.082		5.358		5.909	
Volume (m^3)	43.922		23.581		24.492		32.147		35.452	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.80	0.00
Cotton Bud Sticks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.11	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	113.85	0.00	79.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	833.22	1046.40	247.70	790.90	318.43	567.90	370.15	968.59	974.85	959.45
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	319.95	0.00	63.25	0.00	134.04	17.63	345.38	0.00	174.50	0.00
Tampons	186.50	0.00	28.45	0.00	85.35	0.00	85.26	0.00	80.60	0.00
TOTAL	1453.52	1046.40	419.08	790.90	537.82	585.53	800.79	968.59	1246.86	959.45

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.8 - Inclined Bar Screen (Continued) Sample Mass (Grams)

Sample no.	1		2		3		4		5	
Date & Time	7/6/94	9.45am	7/6/94	9.53am	7/6/94	10.00am	24/5/94	11.10am	24/5/94	11.18am
Flow (m^3/min)	5.449		6.887		3.238		5.137		4.208	
Volume (m^3)	32.696		41.321		19.429		30.825		25.249	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton Bud Sticks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	307.35	970.30	847.97	1182.20	943.38	867.97	0.00	593.20	0.00	398.50
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	27.12	15.95	112.16	0.00	73.00	0.00	164.20	0.00	234.53	20.75
Tampons	60.22	23.72	115.87	0.00	26.79	0.00	0.00	0.00	77.35	0.00
TOTAL	394.69	1009.97	1076.00	1182.20	1043.17	867.97	164.20	593.20	311.88	419.25

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.8 - Inclined Bar Screen (Continued) Sample Mass (Grams)

Sample no.	6		4		5		6		1	
Date & Time	24/5/94	11.25am	25/5/94	10.31am	25/5/94	10.40am	25/5/94	10.49am	1/6/94	10.15am
Flow (m^3/min)	3.311		6.300		6.757		4.166		3.558	
Volume (m^3)	19.867		37.797		40.540		24.996		21.350	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	2.61	1.57	0.00	0.00
Cotton Bud Sticks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	0.00	583.65	91.65	764.85	22.50	1155.40	153.15	1025.10	0.00	580.65
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	141.90	0.00	94.13	0.00	114.85	26.70	113.30	4.09	196.40	0.00
Tampons	0.00	0.00	35.00	0.00	69.70	0.00	119.95	0.00	0.00	21.15
TOTAL	141.90	583.65	220.78	764.85	207.05	1182.10	389.01	1030.76	196.40	601.80

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.9 - D-Screen Sample Mass (Grams)

Sample no.	2		3		4		5		6	
Date & Time	1/6/94	10.22am	1/6/94	10.32am	2/6/94	11.11am	2/6/94	11.20am	2/6/94	11.32am
Flow (m^3/min)	5.626		6.087		3.992		4.200		1.436	
Volume (m^3)	33.753		36.520		23.949		25.200		8.615	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton Bud Sticks	0.00	0.00	0.00	0.00	0.00	0.00	5.20	0.00	0.00	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	0.00	0.00	10.00	0.00	43.80	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	0.00	625.86	0.00	1038.75	320.50	1016.22	111.05	1200.00	0.00	231.00
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	123.10	21.50	297.60	17.70	199.35	0.00	126.33	17.10	213.57	0.00
Tampons	104.15	0.00	0.00	0.00	0.00	0.00	40.20	0.00	43.10	0.00
TOTAL	227.25	647.36	307.60	1056.45	563.65	1016.22	282.78	1217.10	256.67	231.00

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.9 - D-Screen (Continued) Sample Mass (Grams)

Sample no.	4		5		6		4		5	
Date & Time	6/6/94	10.37am	6/6/94	10.45am	6/6/94	10.53am	7/6/94	10.10am	7/6/94	10.17am
Flow (m^3/min)	5.488		2.997		3.393		1.827		4.315	
Volume (m^3)	32.930		17.984		20.357		10.964		25.891	
Samples (grams)	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed	Retained	Passed
Condoms	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton Bud Sticks	6.72	0.00	2.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cloth	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Faeces & Veg. Mat	10.34	0.00	0.00	0.00	28.16	0.00	0.00	0.00	0.00	0.00
F Paper, Veg & Faeces	182.03	1287.83	80.50	570.75	0.00	341.57	0.00	392.60	22.26	948.95
Paper towels	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanitary towels	253.03	0.00	143.35	19.71	83.33	0.00	147.73	0.00	136.60	16.27
Tampons	0.00	0.00	35.40	0.00	67.26	0.00	91.52	0.00	108.10	0.00
TOTAL	452.12	1287.83	261.28	590.46	178.75	341.57	239.25	392.60	266.96	965.22

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.9 - D-Screen (Continued)

Sample Mass (Grams)

Sample no.	6	
Date & Time	7/6/94	10.25am
Flow (m^3/min)	2.105	
Volume (m^3)	12.632	
Samples (grams)	Retained	Passed
Condoms	0.00	0.00
Cotton Bud Sticks	0.00	0.00
Cloth	0.00	0.00
Faeces & Veg. Mat	0.00	0.00
F Paper, Veg & Faeces	0.00	269.39
Paper towels	0.00	0.00
Sanitary towels	11.36	0.00
Tampons	68.71	0.00
TOTAL	80.07	269.39

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen — Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	24/5/94 10.33am			24/5/94 10.45am			24/5/94 10.54am		
Flow (m^3/min)	4.320			6.948			7.295		
Volume (m^3)	25.922			41.689			43.771		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.04	100.0	0.0	0.3	100.0	0.0	0.0	0.0	0.0
Cloth	1.2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	23.8	100.0	0.0	21.6	100.0	0.0	10.6	100.0	0.0
F Paper, Veg & Faeces	67.3	23.5	76.5	71.8	25.6	74.4	84.1	19.6	80.4
Paper towels	0.0	0.0	0.0	3.4	100.0	0.0	0.0	0.0	0.0
Sanitary towels	3.6	100.0	0.0	1.6	72.8	27.2	2.7	100.0	0.0
Tampons	4.0	100.0	0.0	1.3	100.0	0.0	2.6	100.0	0.0
TOTAL	100.0	48.5	51.5	100.0	46.2	53.8	100.0	32.4	67.6

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen (Continued) Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	25/5/94 10.04am			25/5/94 10.12am			25/5/94 10.20am		
Flow (m^3/min)	3.536			4.645			6.253		
Volume (m^3)	21.213			27.872			37.518		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.3	100.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.5	100.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	19.0	100.0	0.0	9.8	100.0	0.0	3.7	100.0	0.0
F Paper, Veg & Faeces	61.5	33.4	66.6	71.1	27.0	73.0	75.2	10.8	89.2
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	11.2	100.0	0.0	8.4	91.1	8.9	12.2	91.9	8.1
Tampons	8.2	100.0	0.0	9.8	100.0	0.0	8.9	100.0	0.0
TOTAL	100.0	59.0	41.0	100.0	47.4	52.6	100.0	32.0	68.0

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen (Continued) — Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	1/6/94 10.53am			1/6/94 11.01am			1/6/94 11.08am		
Flow (m^3/min)	3.841			2.976			5.431		
Volume (m^3)	23.045			17.856			32.589		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	98.0	18.5	81.5	90.5	39.2	60.8	79.7	48.2	51.8
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	2.0	100.0	0.0	7.4	0.0	100.0	10.1	100.0	0.0
Tampons	0.0	0.0	0.0	2.1	0.0	100.0	10.2	100.0	0.0
TOTAL	100.0	20.1	79.9	100.0	35.5	64.5	100.0	58.7	41.3

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	2/6/94 10.41am			2/6/94 10.50am			2/6/94 10.59am		
Flow (m^3/min)	6.202			7.320			6.431		
Volume (m^3)	37.210			43.922			23.581		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	4.6	0.0	100.0	6.6	100.0	0.0
F Paper, Veg & Faeces	80.2	46.0	54.0	75.2	55.7	44.3	85.8	23.8	76.2
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	8.5	100.0	0.0	12.8	0.0	100.0	5.2	100.0	0.0
Tampons	10.8	0.0	0.0	7.5	0.0	100.0	2.4	100.0	0.0
TOTAL	100.0	56.7	43.3	100.0	41.9	58.1	100.0	34.6	65.4

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	6/6/94 10.12am			6/6/94 10.19am			6/6/94 10.26am		
Flow (m^3/min)	4.082			5.358			9.669		
Volume (m^3)	24.492			32.147			35.452		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.5	100.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.2	100.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	78.9	35.9	64.1	75.7	27.6	72.4	87.7	50.4	49.6
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	13.5	88.4	11.6	19.5	100.0	0.0	7.9	100.0	0.0
Tampons	7.6	0.0	0.0	4.8	100.0	0.0	3.7	100.0	0.0
TOTAL	100.0	47.9	52.1	100.0	45.3	54.7	100.0	56.5	43.5

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.10 - Inclined Bar Screen (Continued) Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	7/6/94			7/6/94			7/6/94		
Flow (m^3/min)	5.449			6.887			3.238		
Volume (m^3)	32.696			41.321			19.429		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	91.0	24.1	75.9	89.9	41.8	58.2	94.8	52.1	47.9
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	3.1	63.0	37.0	5.0	100.0	0.0	3.8	100.0	0.0
Tampons	6.0	0.0	0.0	5.1	100.0	0.0	1.4	100.0	0.0
TOTAL	100.0	28.1	71.9	100.0	47.6	52.4	100.0	54.6	45.4

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen — Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	24/5/94 11.10am			24/5/94 11.18am			24/5/94 11.25am		
Flow (m^3/min)	5.137			4.208			3.311		
Volume (m^3)	30.825			25.249			19.867		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	78.3	0.0	100.0	54.5	0.0	100.0	80.4	0.0	100.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	21.7	100.0	0.0	34.9	91.9	8.1	19.6	100.0	0.0
Tampons	0.0	0.0	0.0	10.6	100.0	0.0	0.0	0.0	0.0
TOTAL	100.0	21.7	78.3	100.0	42.7	57.3	100.0	19.6	80.4

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen (Continued) Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	25/5/94 10.31am			25/5/94 10.40am			25/5/94 10.49am		
Flow (m^3/min)	6.300			6.757			4.166		
Volume (m^3)	37.797			40.540			24.996		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.3	62.4	37.6
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	86.9	10.7	89.3	84.8	1.9	98.1	83.0	13.0	87.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	9.6	100.0	0.0	10.2	81.1	18.9	8.3	96.5	3.5
Tampons	3.6	100.0	0.0	5.0	100.0	0.0	8.4	100.0	0.0
TOTAL	100.0	22.4	77.6	100.0	14.9	85.1	100.0	27.4	72.6

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen (Continued)

Efficiencies & Percentage of overall Sample Mass

Sample no.	1			2			3		
Date & Time	1/6/94 10.15am			1/6/94 10.22am			1/6/94 10.32am		
Flow (m^3/min)	3.558			5.626			6.087		
Volume (m^3)	21.350			33.753			36.520		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.7	100.0	0.0
F Paper, Veg & Faeces	72.7	0.0	100.0	71.6	0.0	100.0	76.2	0.0	100.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	24.6	100.0	0.0	16.5	85.1	14.9	23.1	94.4	5.6
Tampons	2.6	0.0	100.0	11.9	100.0	0.0	0.0	0.0	0.0
TOTAL	100.0	24.6	75.4	100.0	26.0	74.0	100.0	22.6	77.4

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen (Continued)   Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	2/6/94 11.11am			2/6/94 11.20am			2/6/94 11.32am		
Flow (m^3/min)	3.992			4.200			1.436		
Volume (m^3)	23.949			25.200			8.615		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.3	100.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	2.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	84.6	24.0	76.0	87.4	8.5	91.5	47.4	0.0	100.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	12.6	100.0	0.0	9.6	88.1	11.9	43.8	100.0	0.0
Tampons	0.0	0.0	0.0	2.7	100.0	0.0	8.8	100.0	0.0
TOTAL	100.0	35.7	64.3	100.0	18.9	81.1	100.0	52.6	47.4

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen (Continued) Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	6/6/94 10.37am			6/6/94 10.45am			6/6/94 10.53am		
Flow (m^3/min)	5.488			2.997			3.393		
Volume (m^3)	32.930			17.984			20.357		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.4	100.0	0.0	0.2	100.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.6	100.0	0.0	0.0	0.0	0.0	5.4	100.0	0.0
F Paper, Veg & Faeces	84.5	12.4	87.6	76.5	12.4	87.6	65.6	0.0	100.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	14.5	100.0	0.0	19.1	87.9	12.1	16.0	100.0	0.0
Tampons	0.0	0.0	0.0	4.2	100.0	0.0	12.9	100.0	0.0
TOTAL	100.0	26.0	74.0	100.0	30.7	69.3	100.0	34.4	65.6

SAMPLE CLASSIFICATION - Long Lane Sewage Treatment Works

Table 3.11 - D-Screen (Continued) Efficiencies & Percentage of overall Sample Mass

Sample no.	4			5			6		
Date & Time	7/6/94 10.10am			7/6/94 10.17am			7/6/94 10.25am		
Flow (m^3/min)	1.827			4.315			2.105		
Volume (m^3)	10.964			25.891			12.632		
Samples (grams)	% sample	Retained	Passing	% sample	Retained	Passing	% sample	Retained	Passing
Condoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cotton Bud Sticks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cloth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Faeces & Veg. Mat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
F Paper, Veg & Faeces	62.1	0.0	100.0	78.8	2.3	97.7	77.1	0.0	100.0
Paper towels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sanitary towels	23.4	100.0	0.0	12.4	89.4	10.6	3.3	100.0	0.0
Tampons	14.5	0.0	0.0	8.8	100.0	0.0	19.7	100.0	0.0
TOTAL	100.0	37.9	62.1	100.0	21.7	78.3	100.0	22.9	77.1

Sharpe & Kirkbride Stilling pond CSO

Total gross solids mass against Mean Overflow Intensity

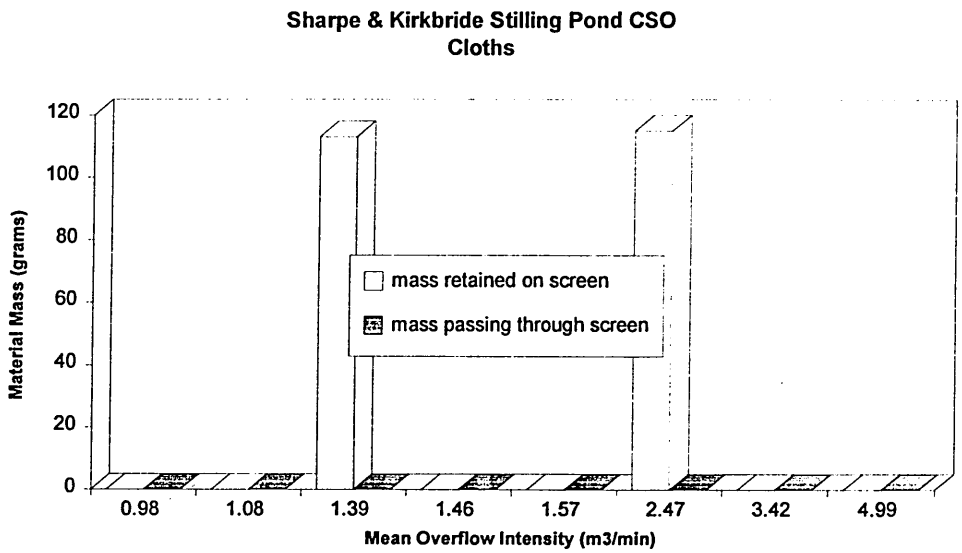


Figure 3.31

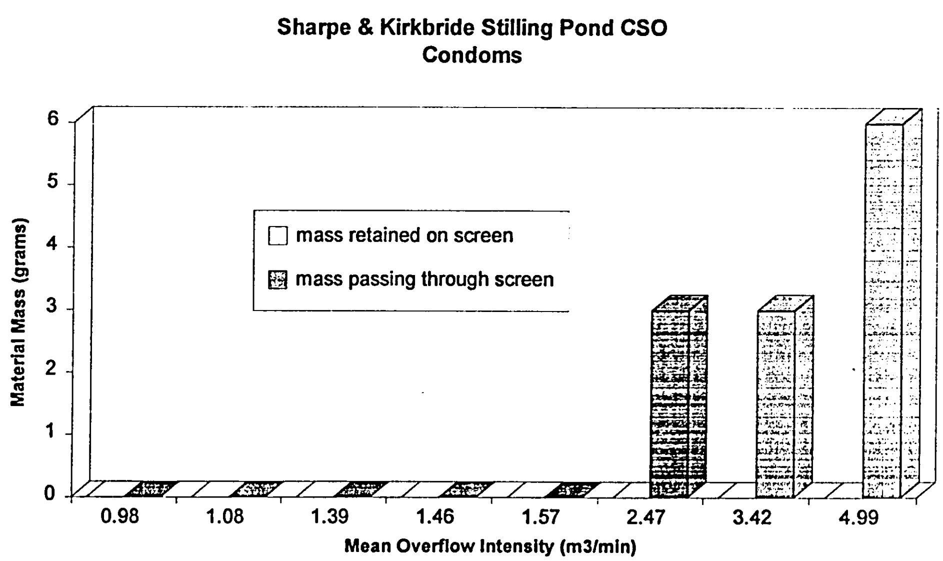


Figure 3.32

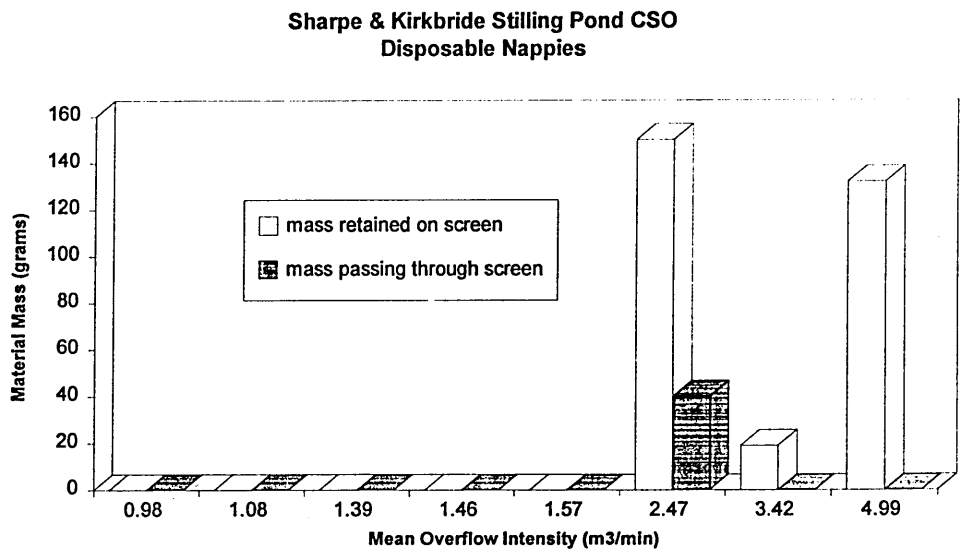


Figure 3.33

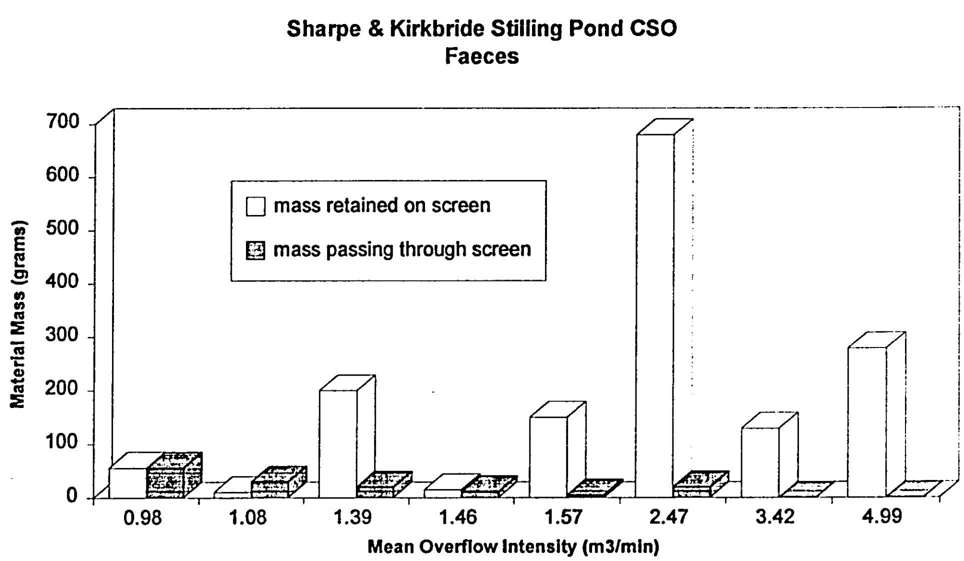


Figure 3.34

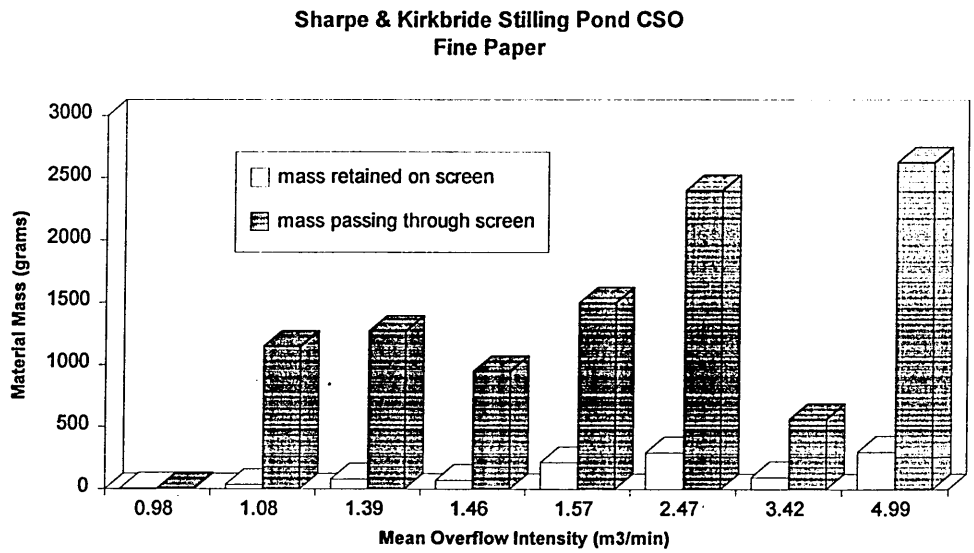


Figure 3.35

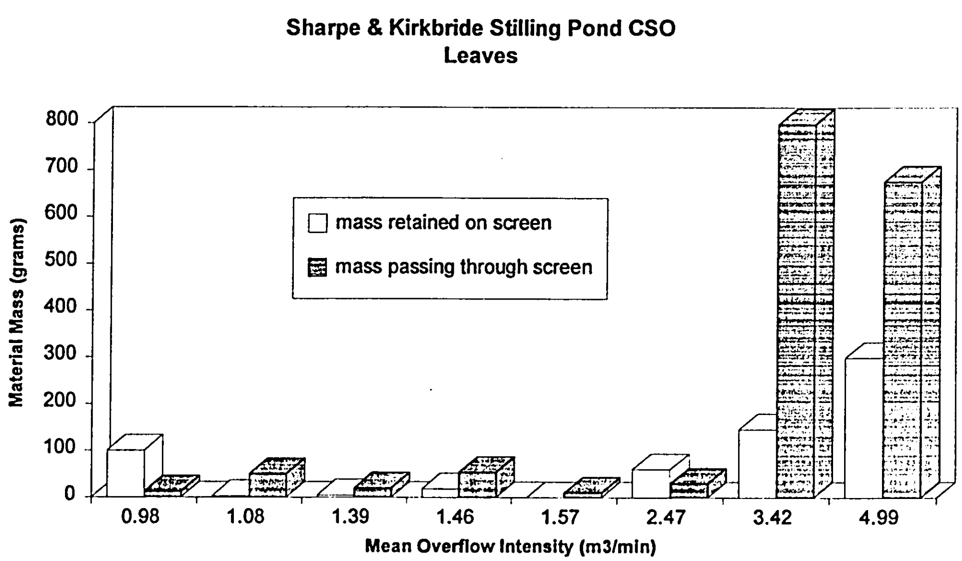


Figure 3.36

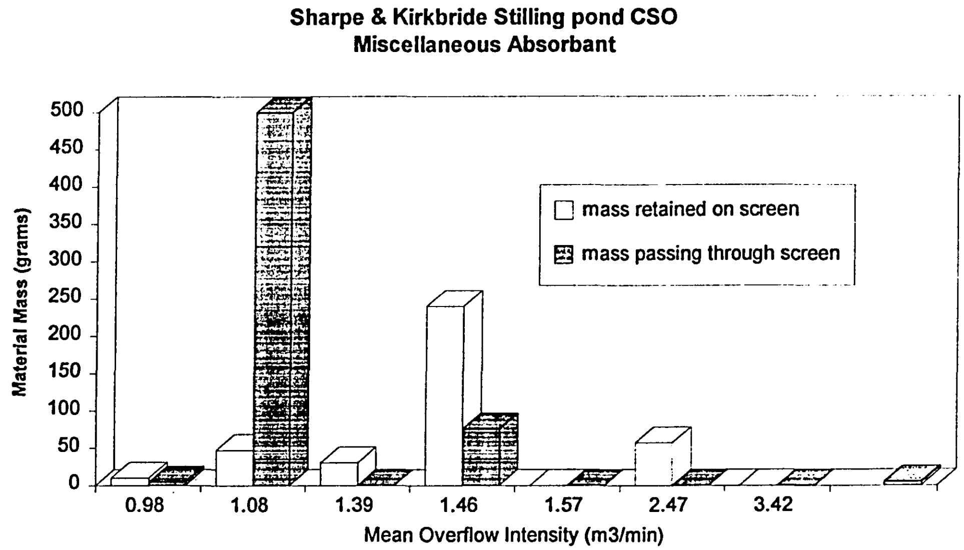


Figure 3.37

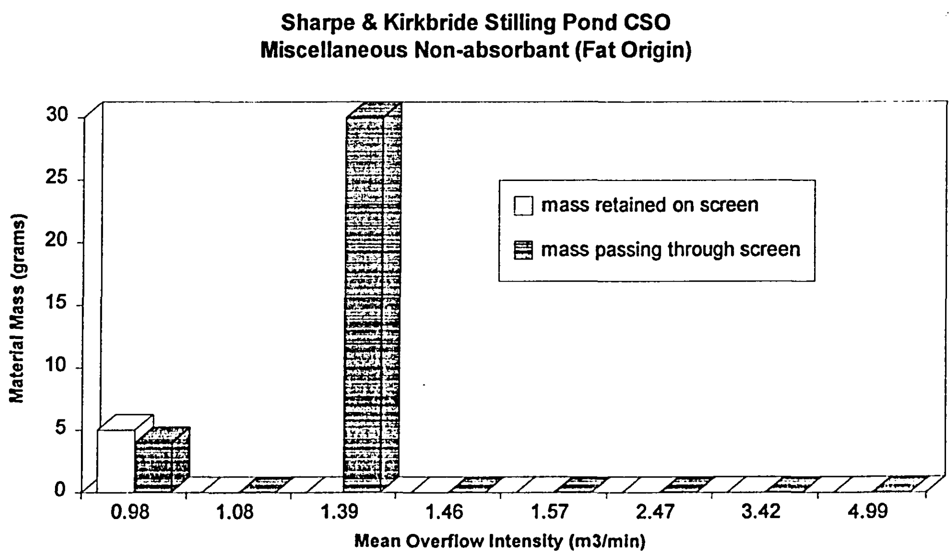


Figure 3.38

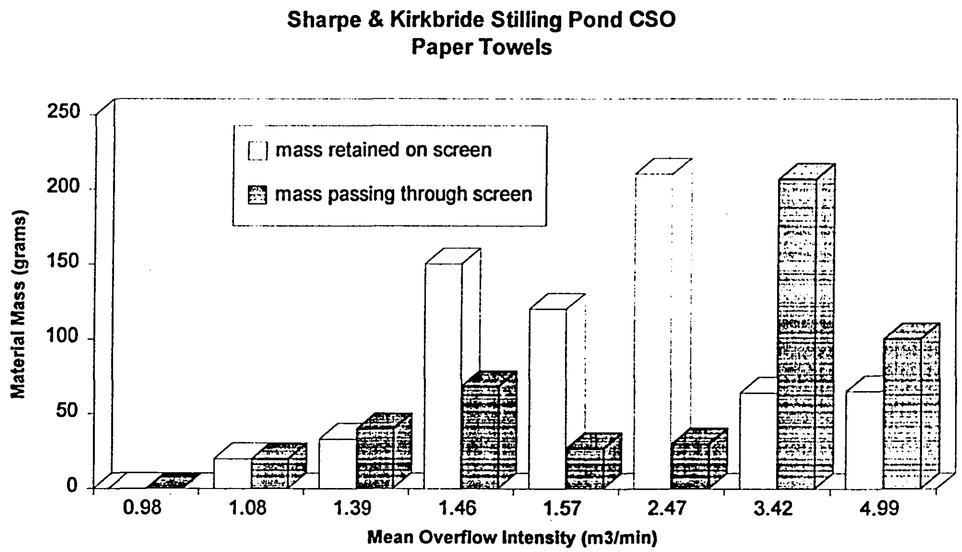


Figure 3.39

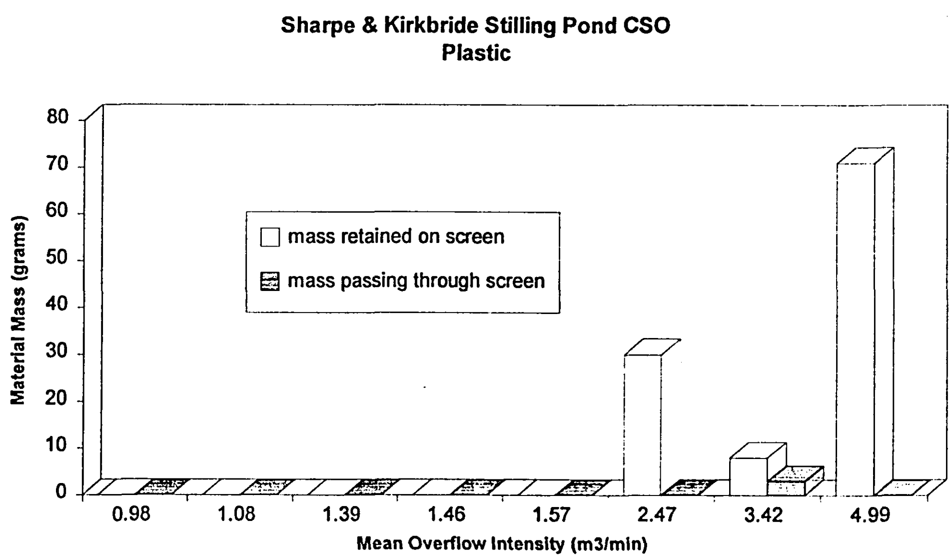


Figure 3.40

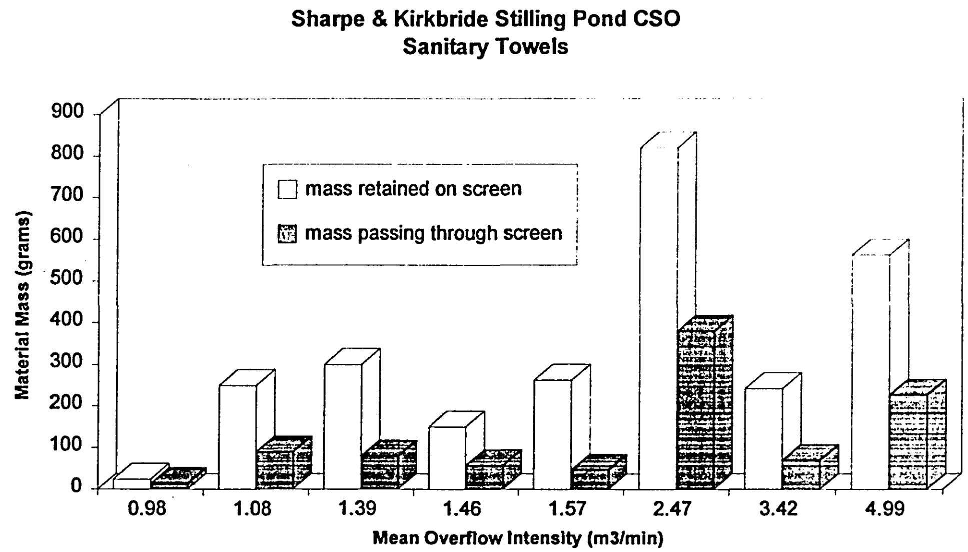


Figure 3.41

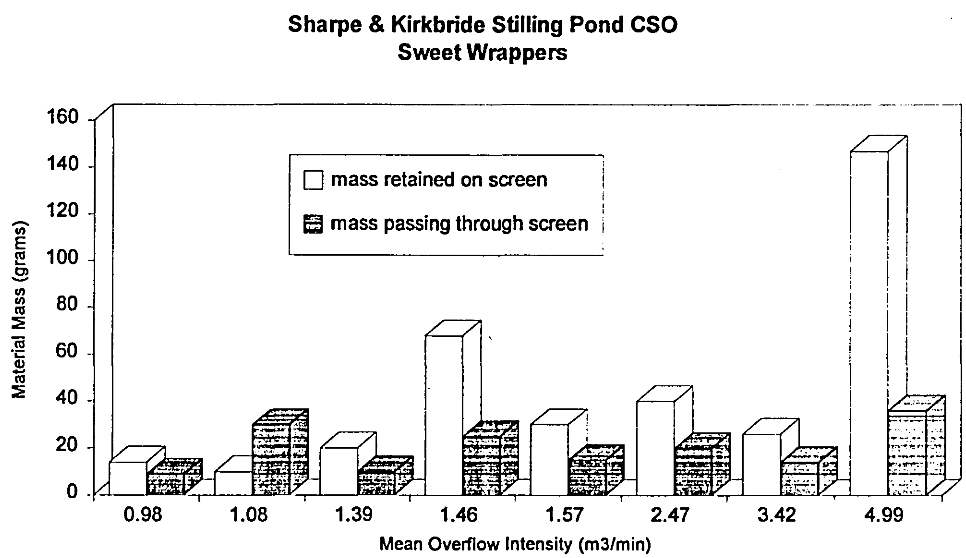


Figure 3.42

Sharpe & Kirkbride Stilling Pond CSO
Tampons

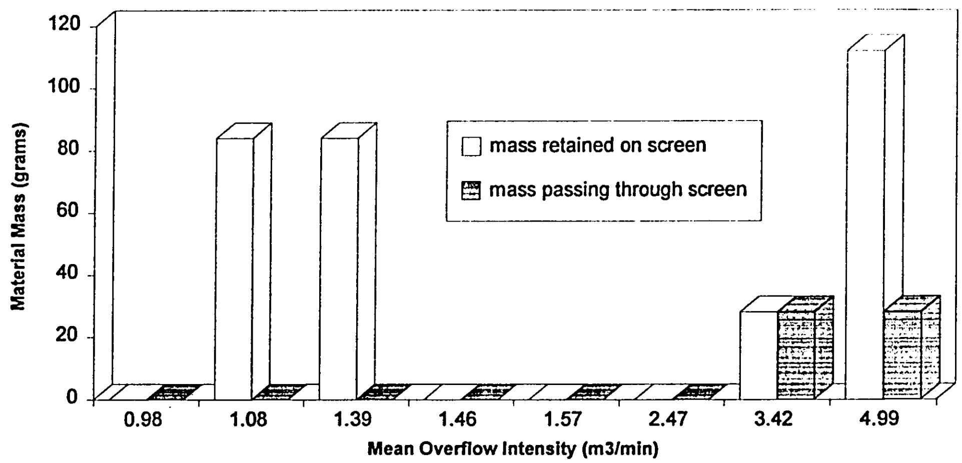


Figure 3.43

Extended Stilling pond CSO

Total gross solids mass against Mean Overflow Intensity

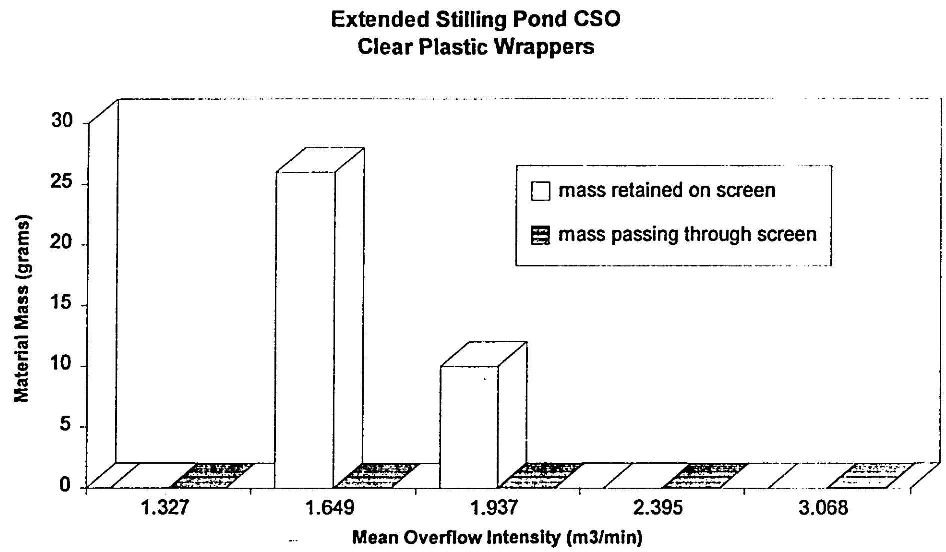


Figure 3.44

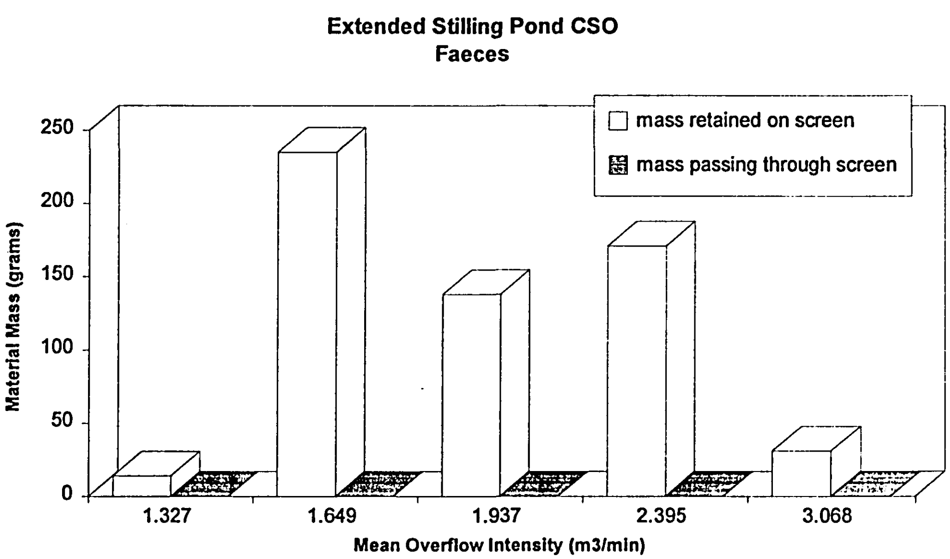


Figure 3.45

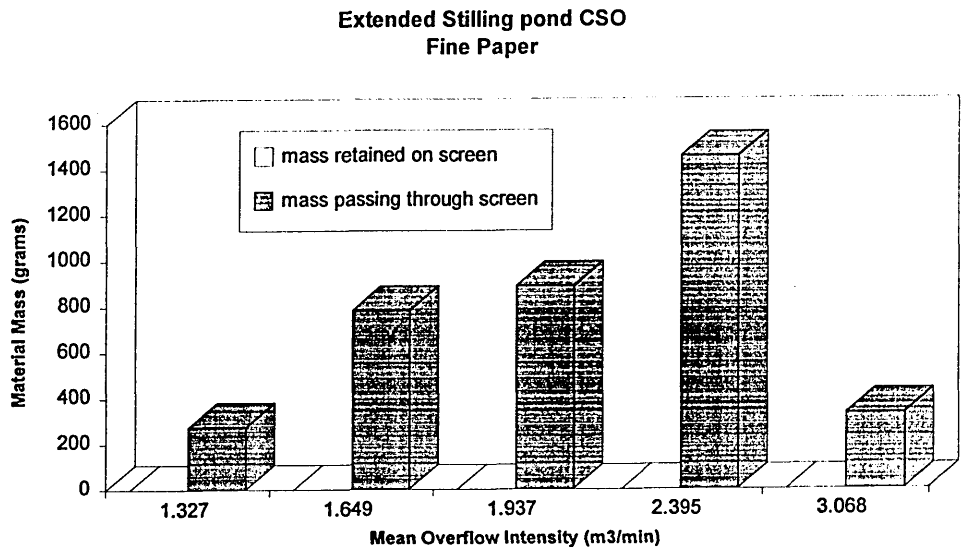


Figure 3.46

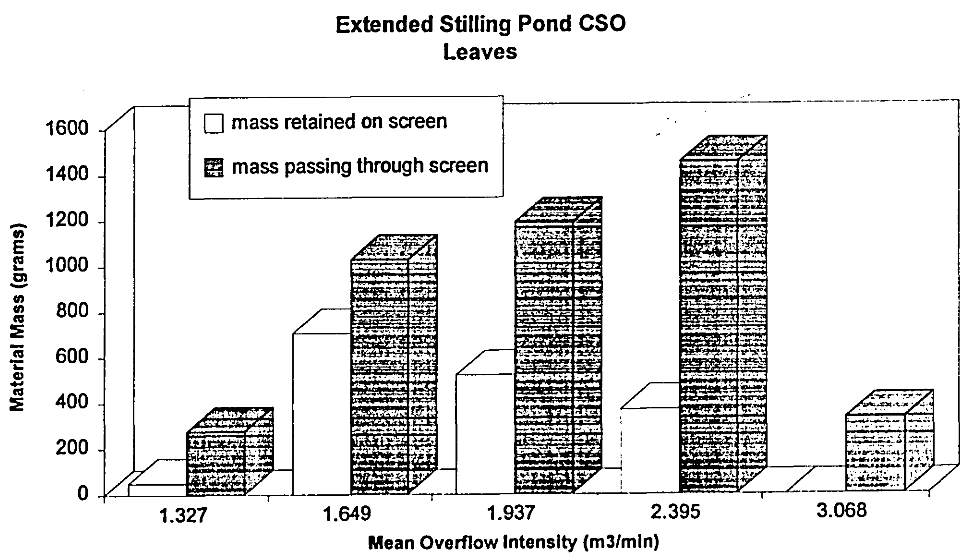


Figure 3.47

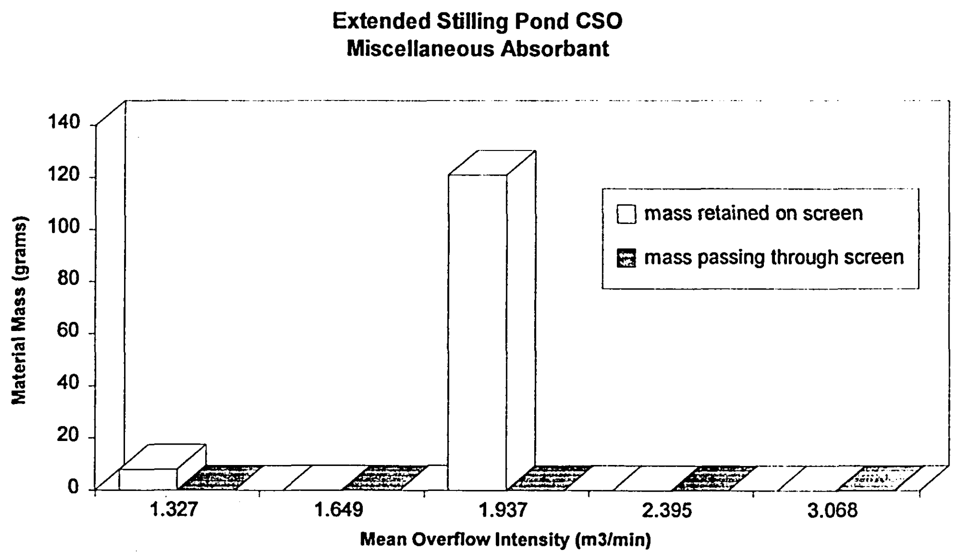


Figure 3.48

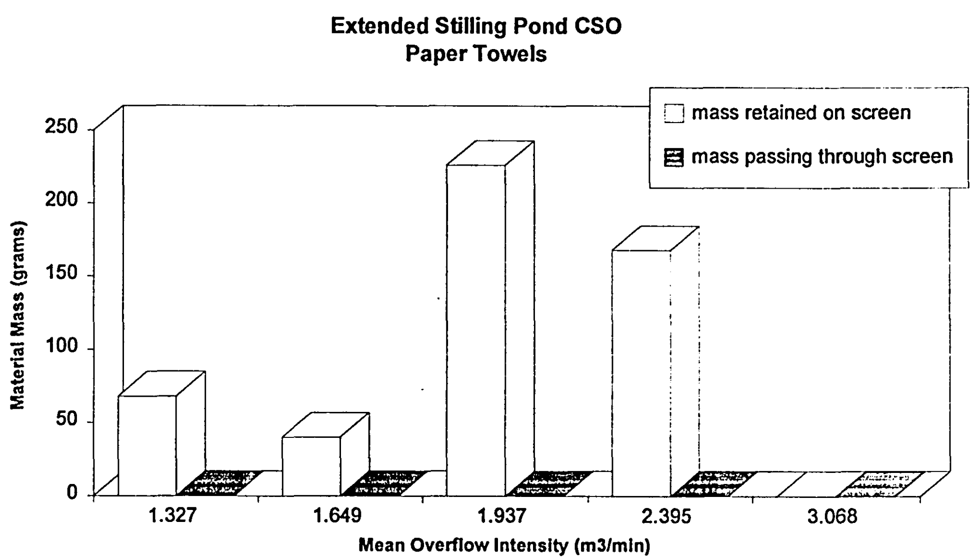


Figure 3.49

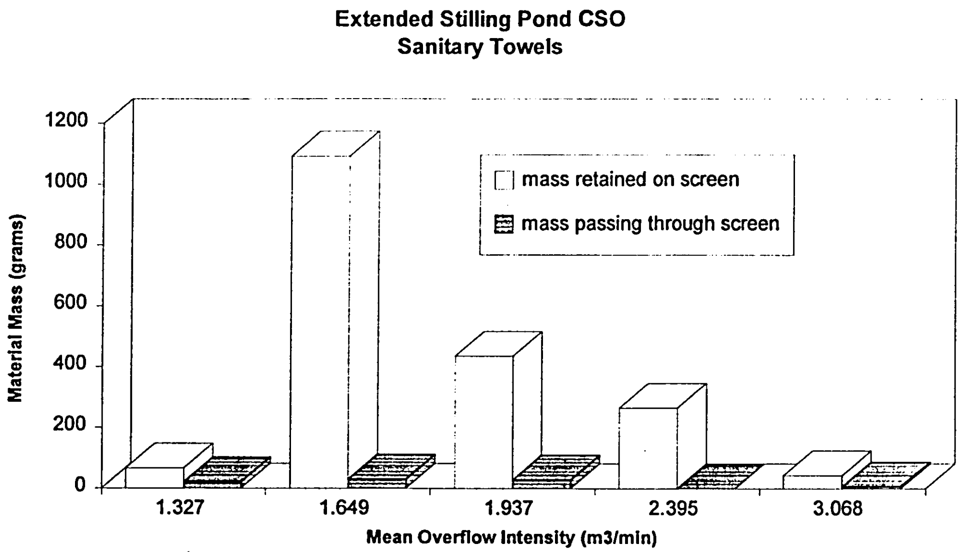


Figure 3.50

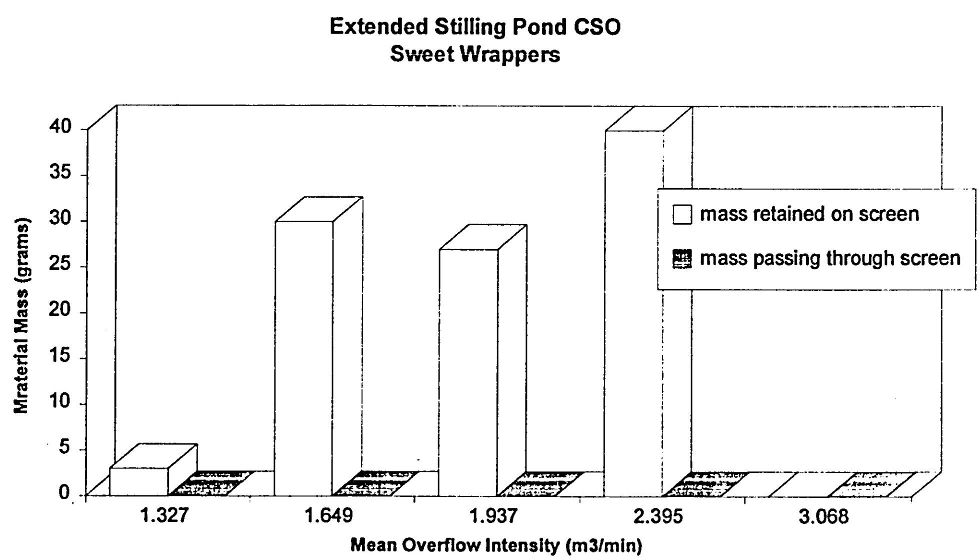


Figure 3.51

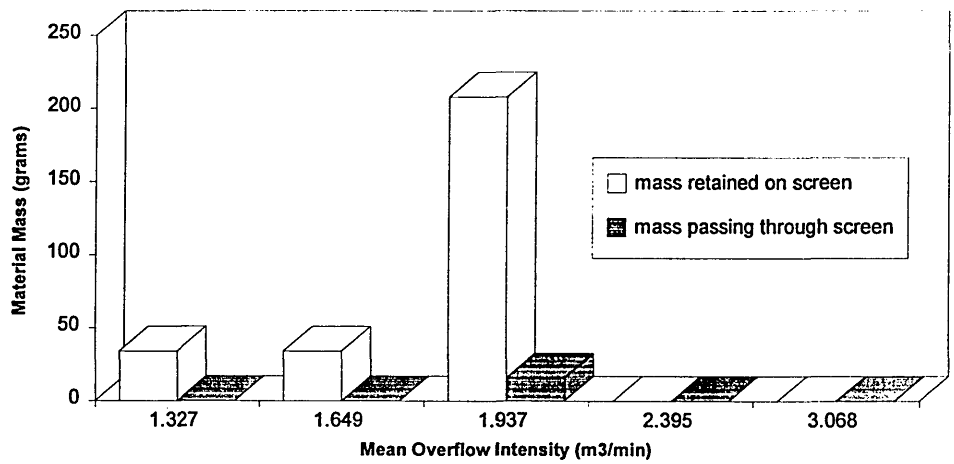


Figure 3.52

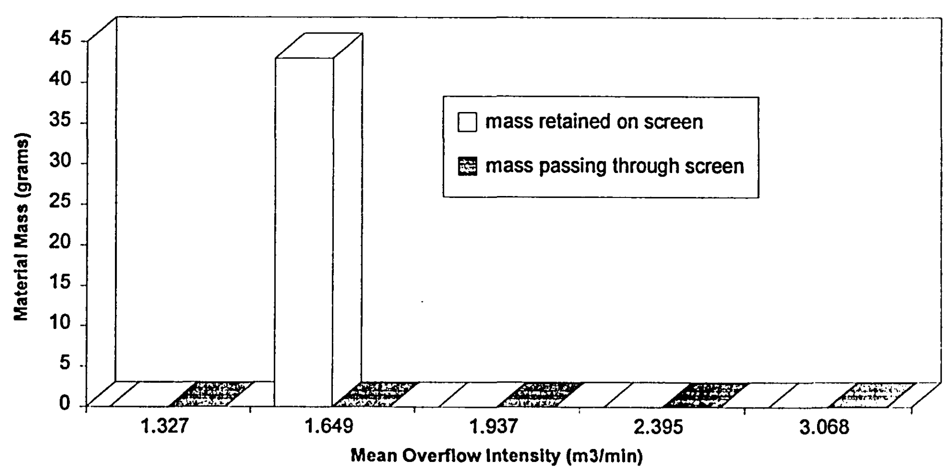


Figure 3.53

Sharpe & Kirkbride Stilling pond CSO

Total gross solids mass against Max. Flowrate

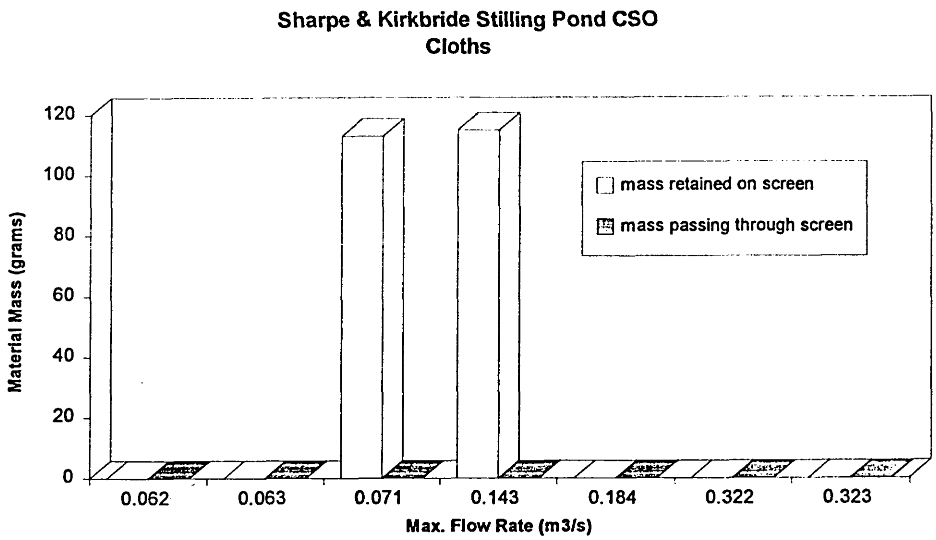


Figure 3.54

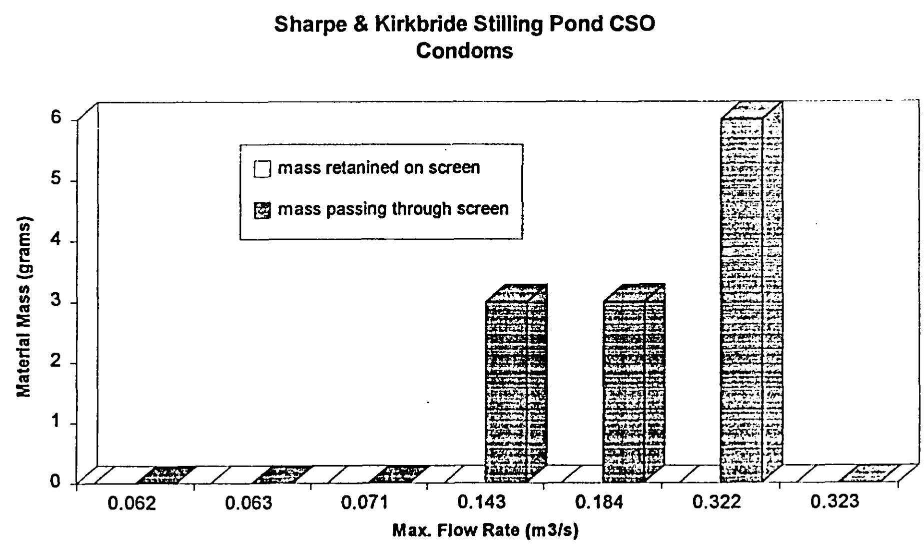


Figure 3.55

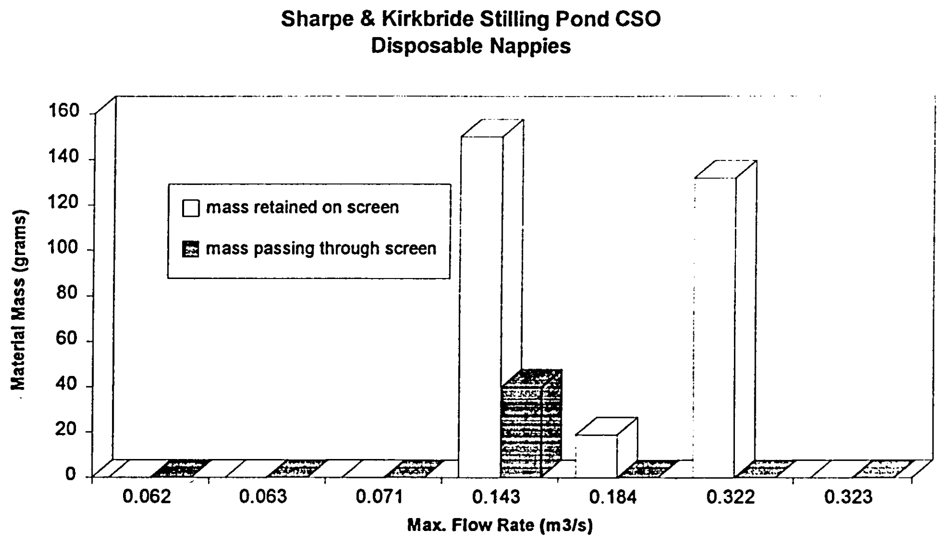


Figure 3.56

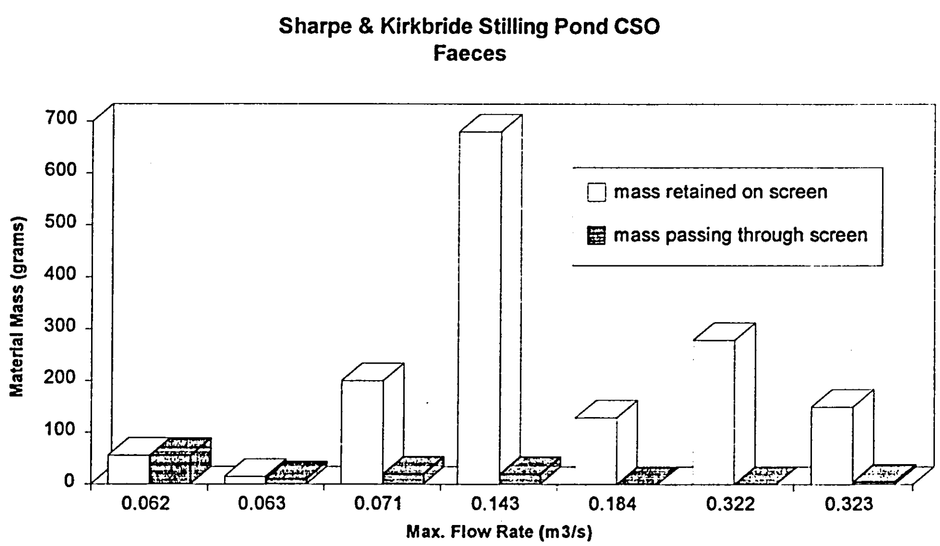


Figure 3.57

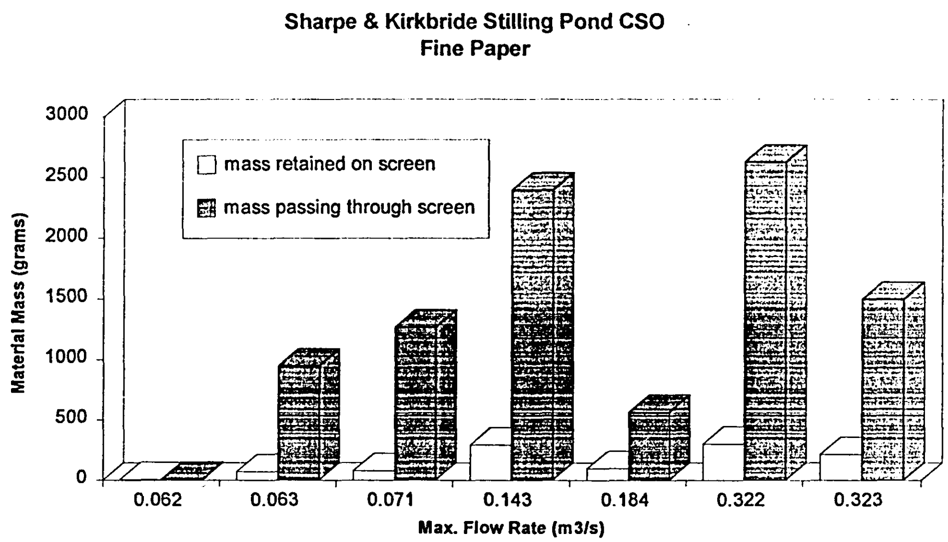


Figure 3.58

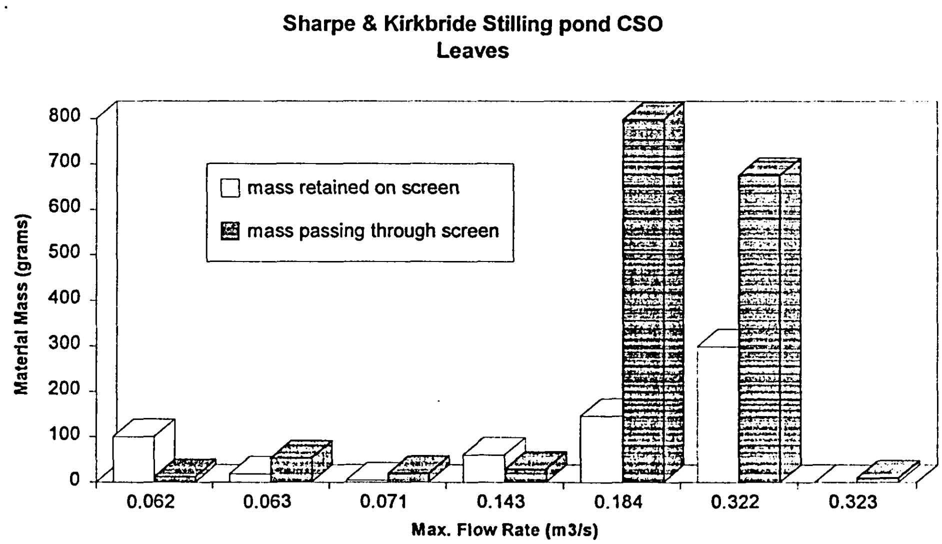


Figure 3.59

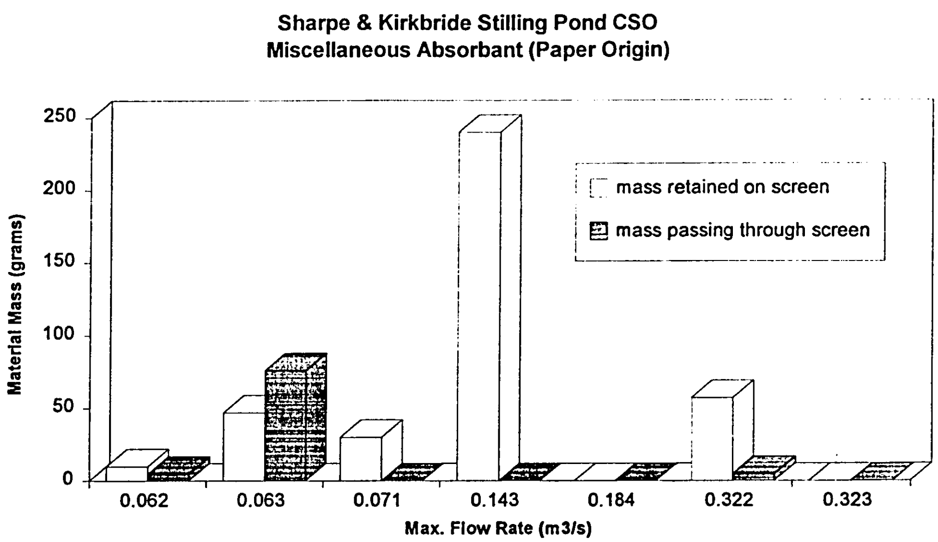


Figure 3.60

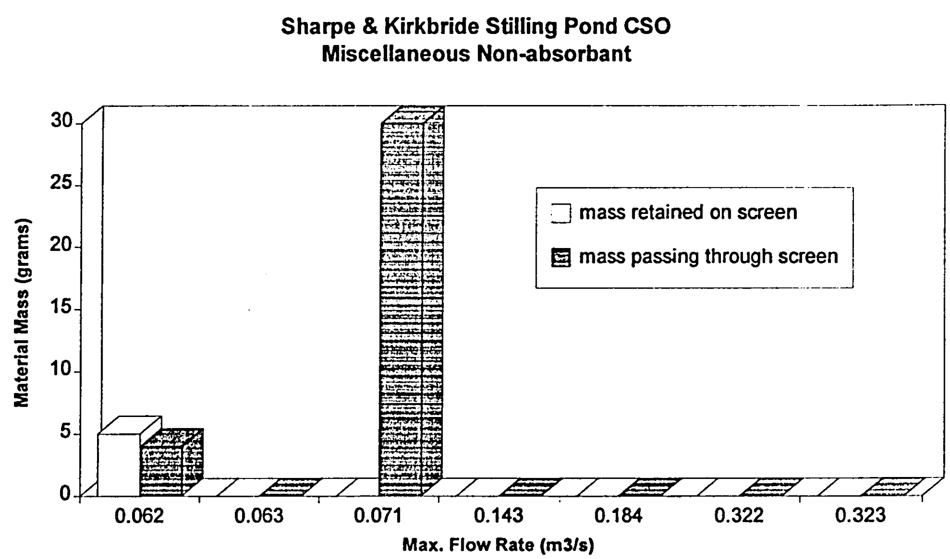


Figure 3.61

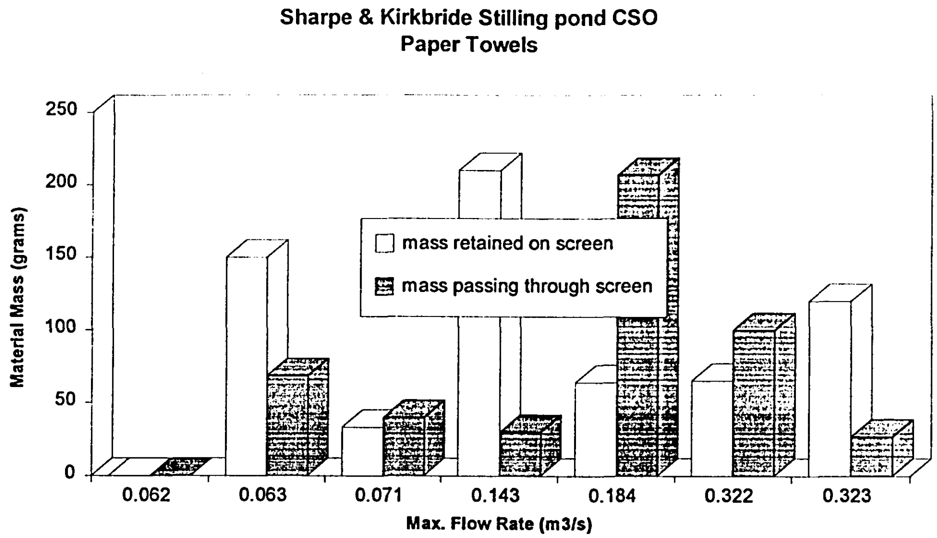


Figure 3.62

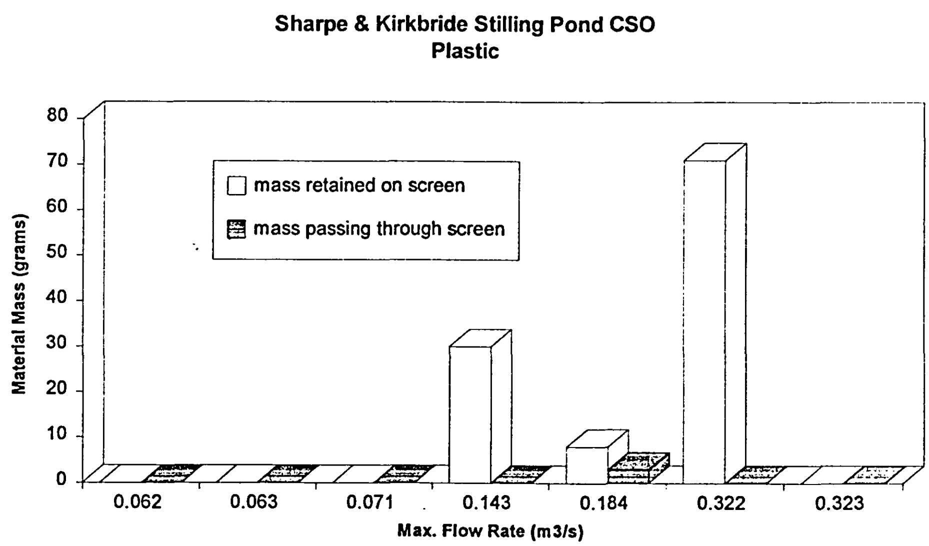


Figure 3.63

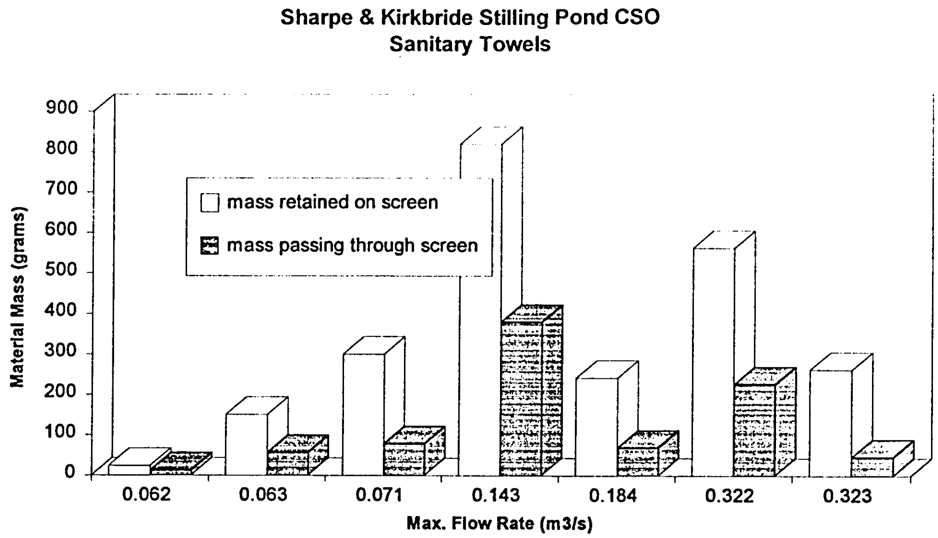


Figure 3.64

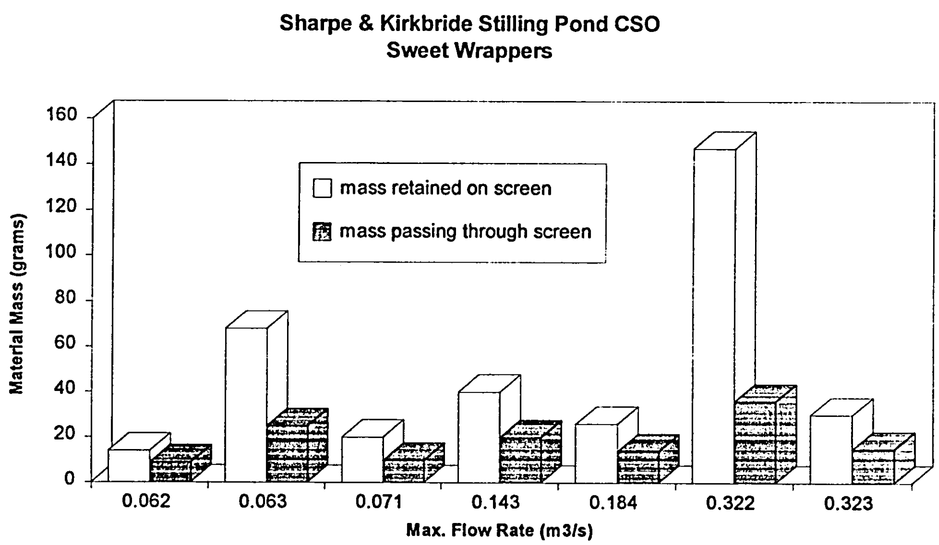


Figure 3.65

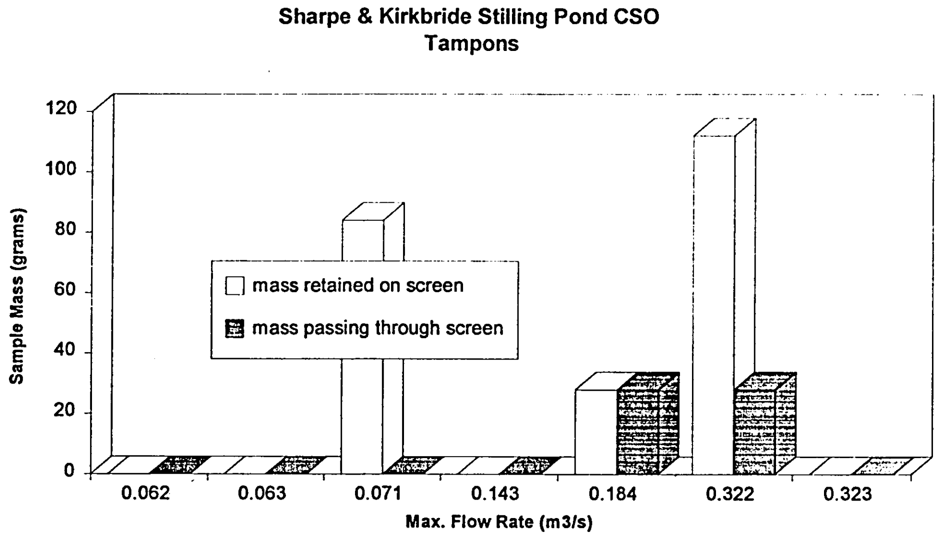

Sharpe & Kirkbride Stilling Pond CSO
Tampons
Sample Mass (grams)
120
100
80
60
40
20
0
mass retained on screen
mass passing through screen
0.062
0.063
0.071
0.143
0.184
0.322
0.323
Max. Flow Rate (m3/s)

Figure 3.66

Extended Stilling pond CSO

Total gross solids mass against Max. Flowrate

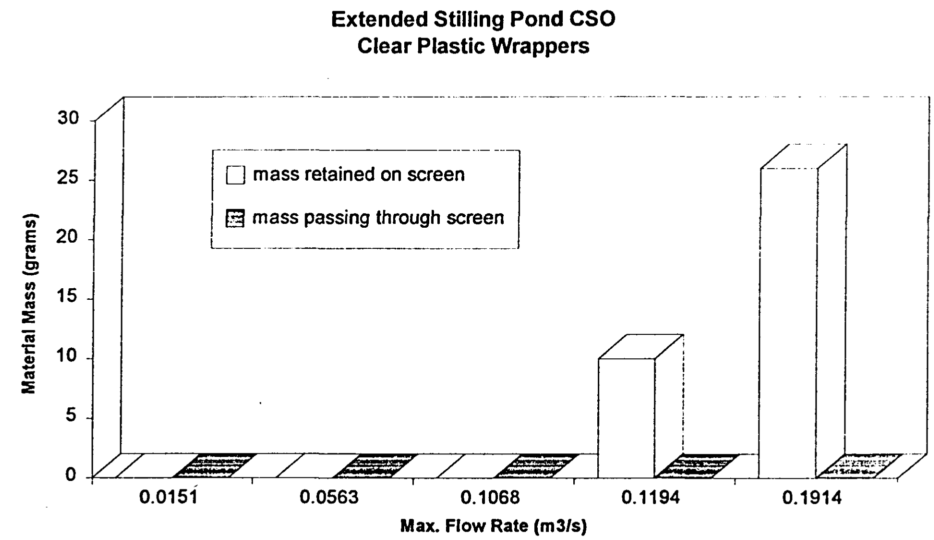


Figure 3.67

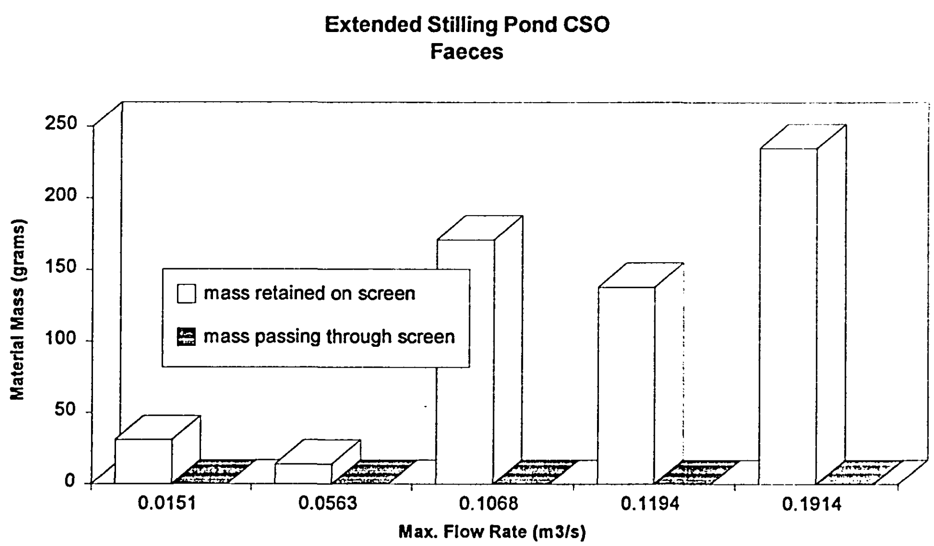


Figure 3.68

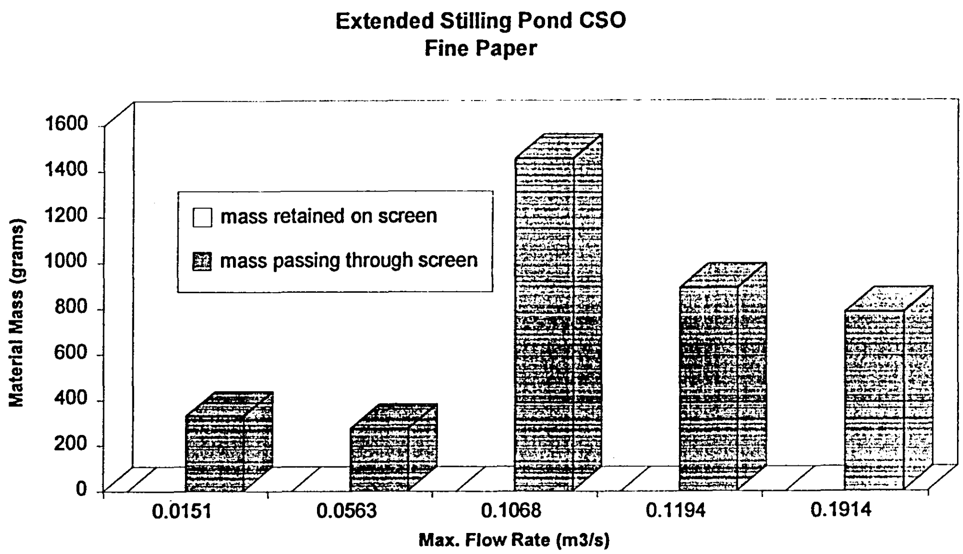


Figure 3.69

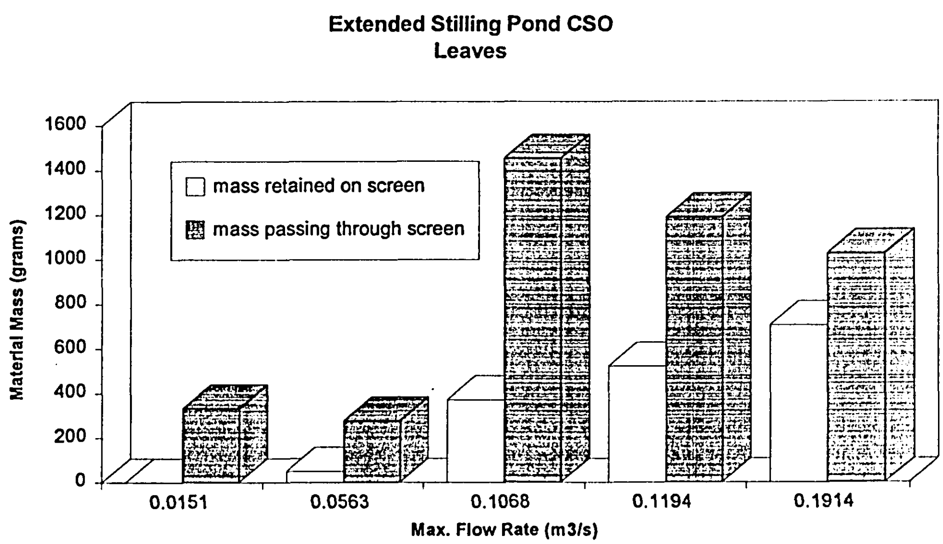


Figure 3.70

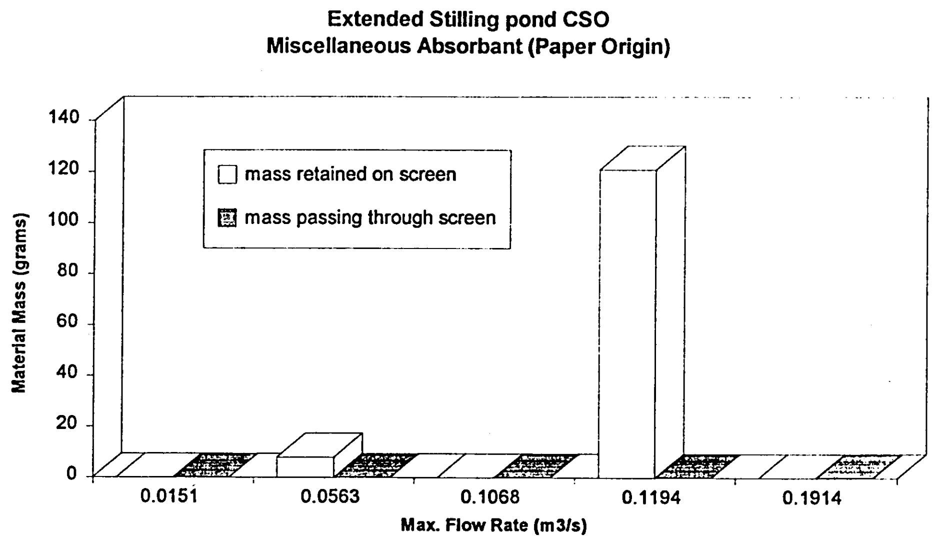


Figure 3.71

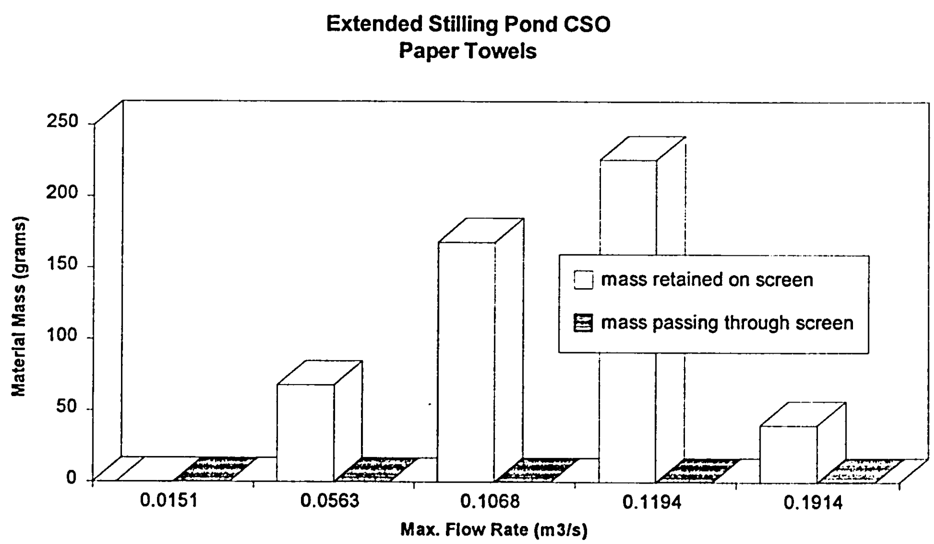


Figure 3.72

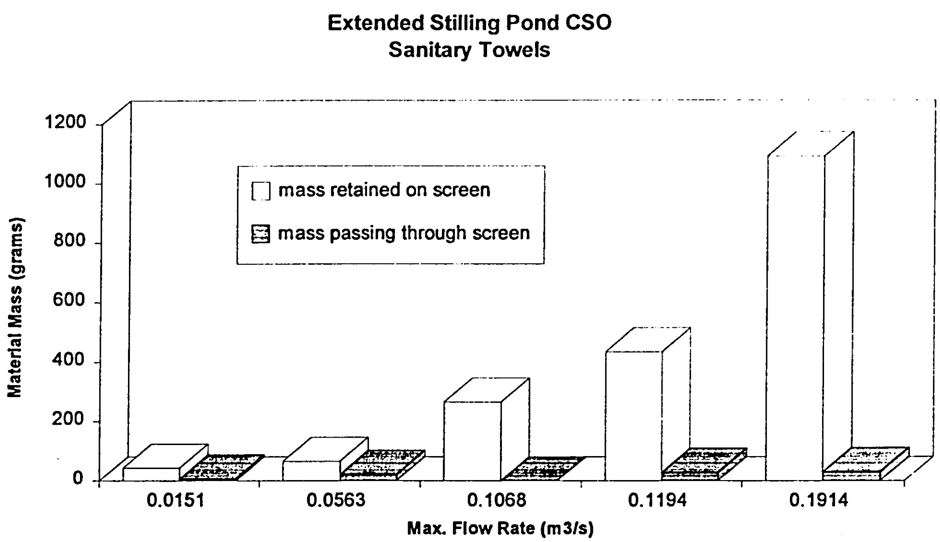


Figure 3.73

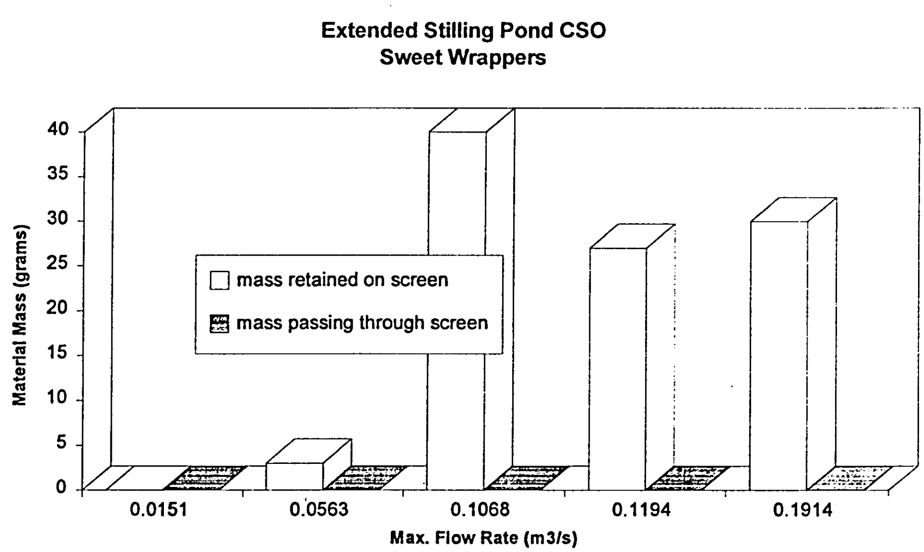


Figure 3.74

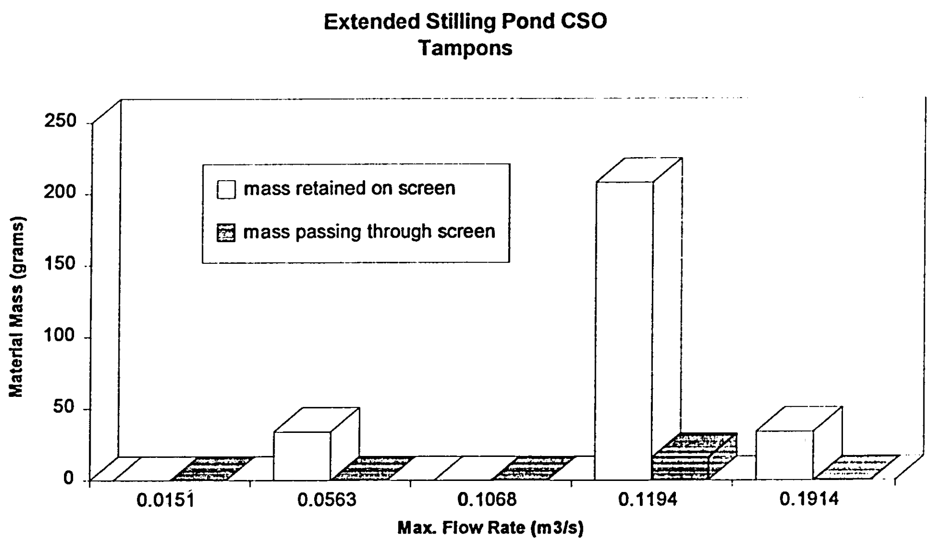


Figure 3.75

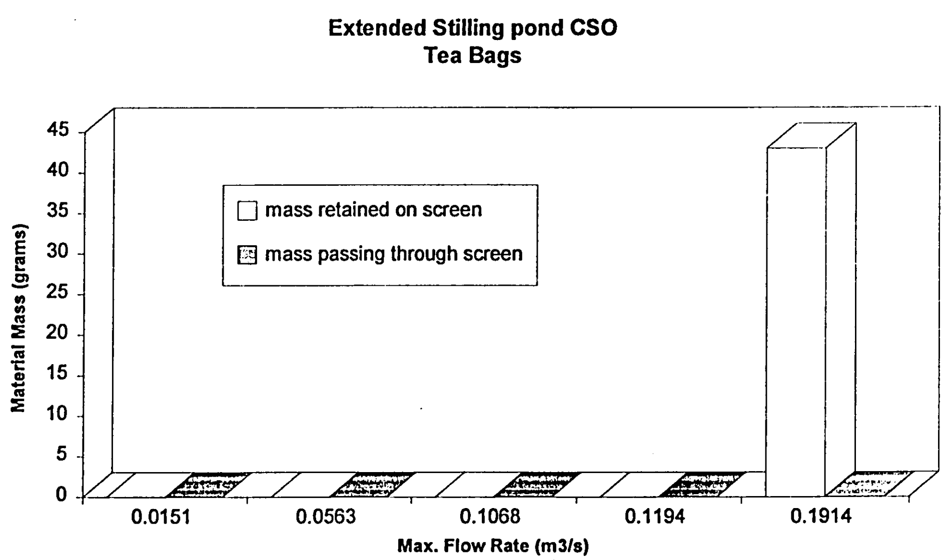


Figure 3.76

Sharpe & Kirkbride Stilling pond CSO

Screen Retention Efficiency against Max. Flowrate

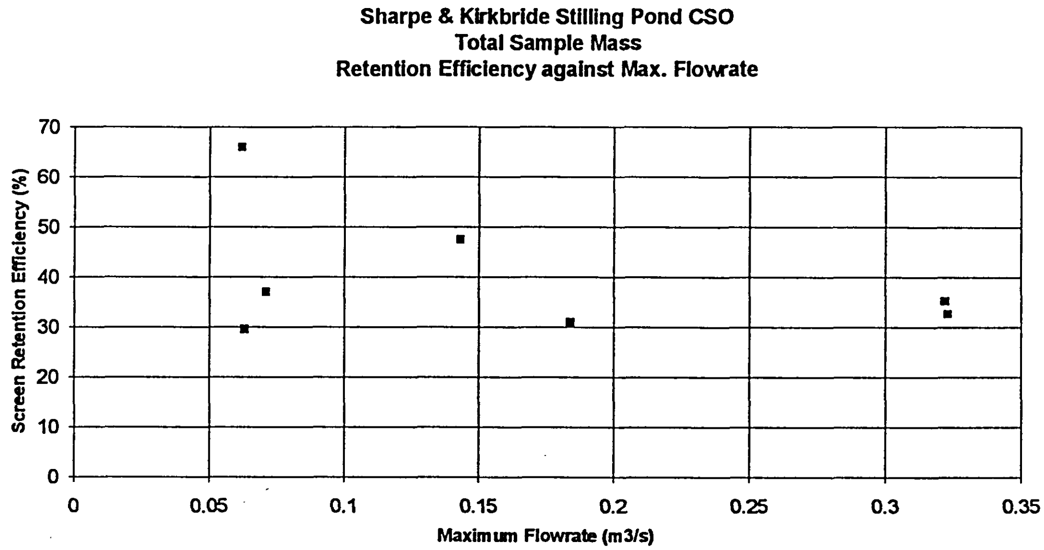


Figure 3.77

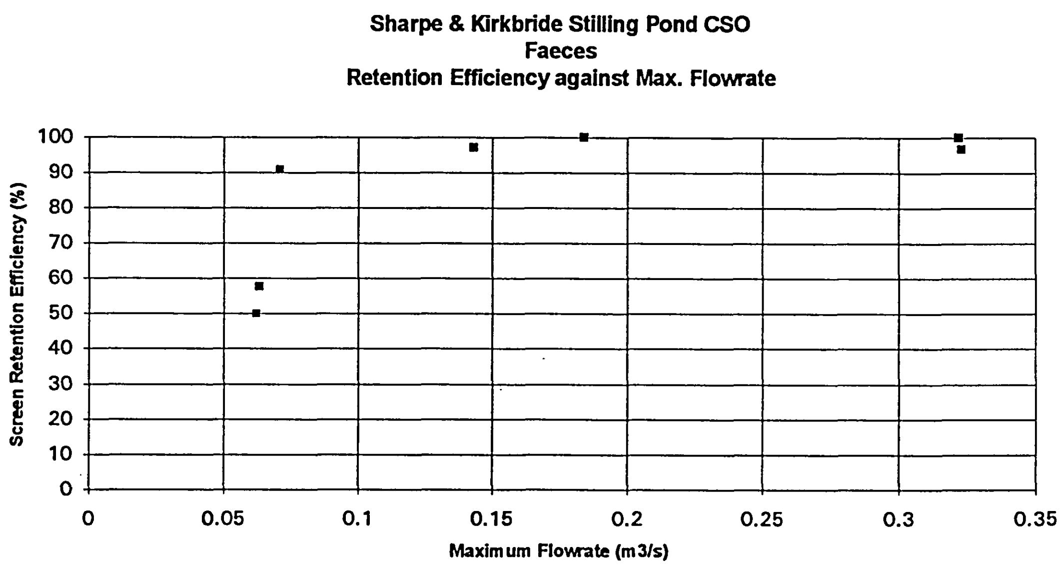


Figure 3.78

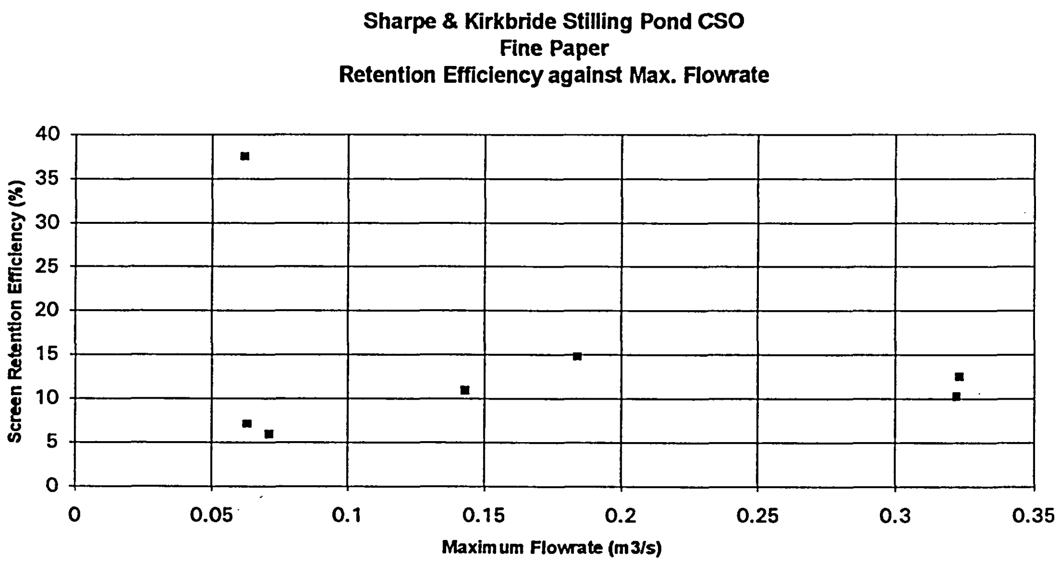


Figure 3.79

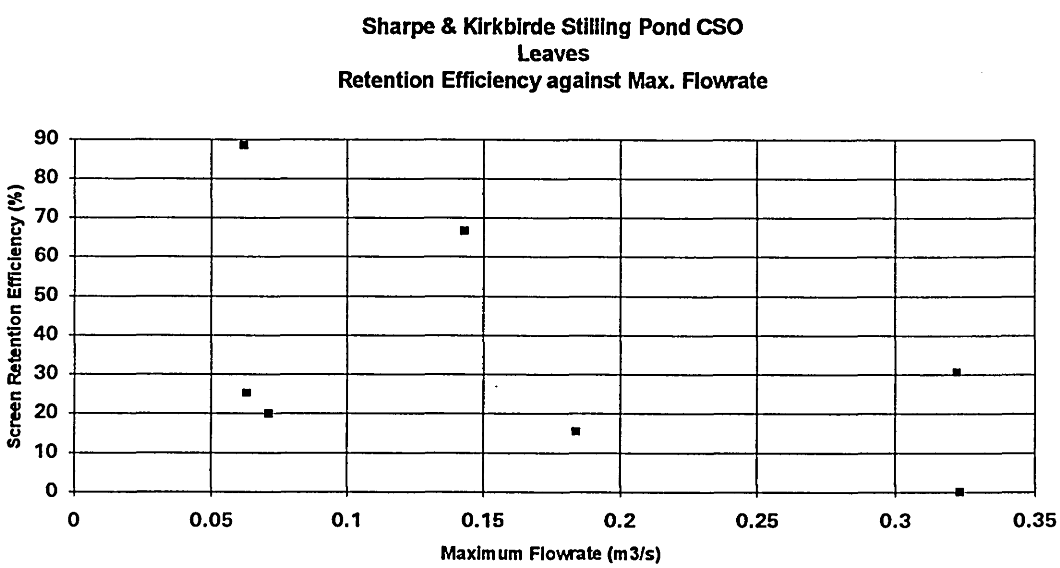


Figure 3.80

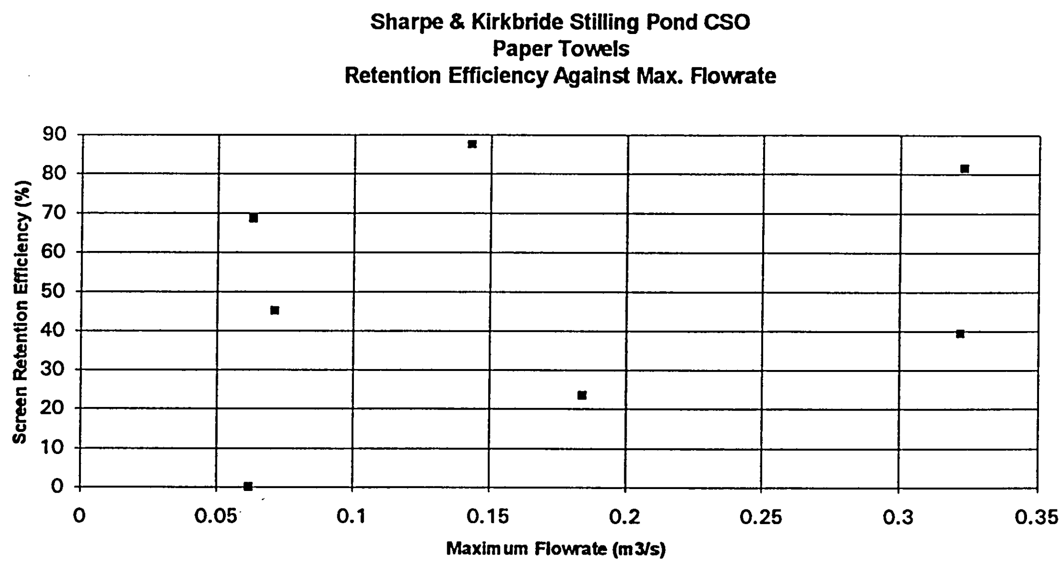


Figure 3.81

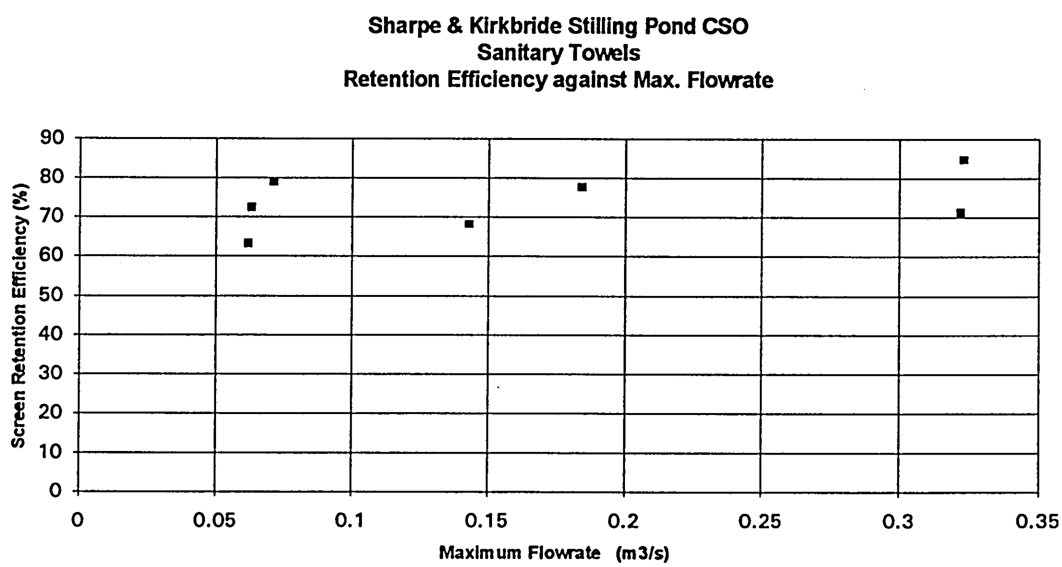


Figure 3.82

Extended Stilling pond CSO

Screen Retention Efficiency against Max. Flowrate

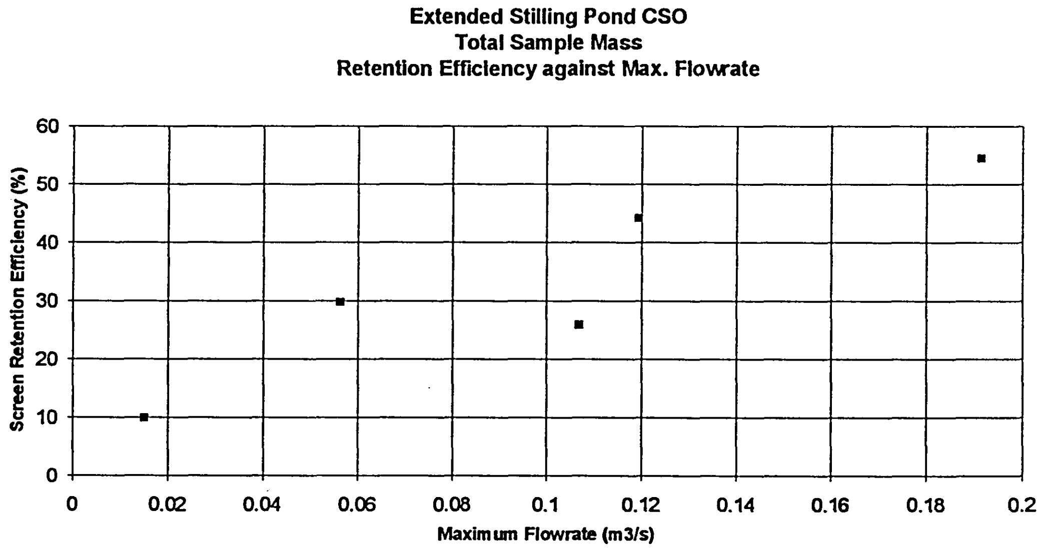


Figure 3.83

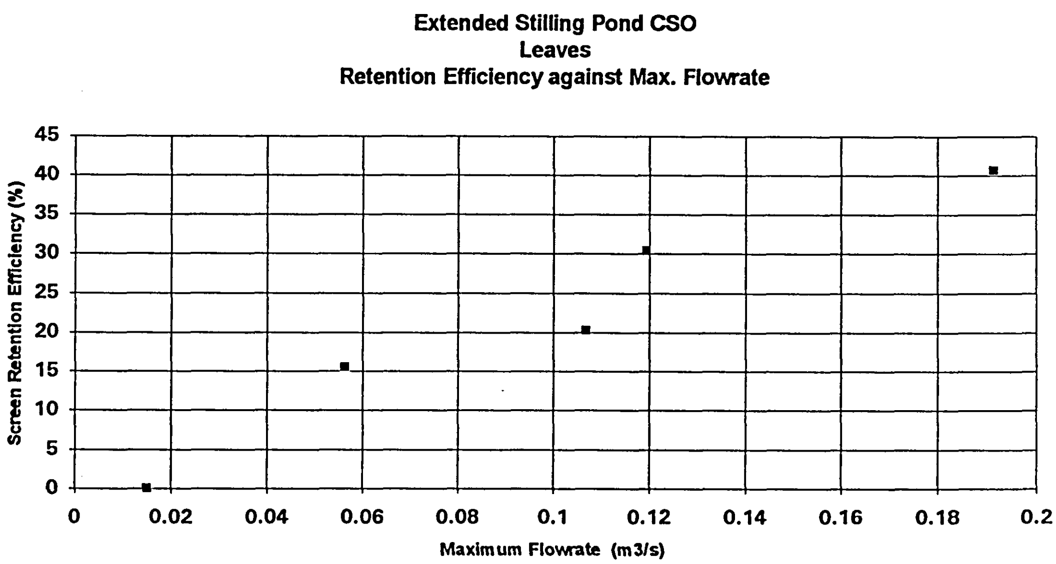


Figure 3.84

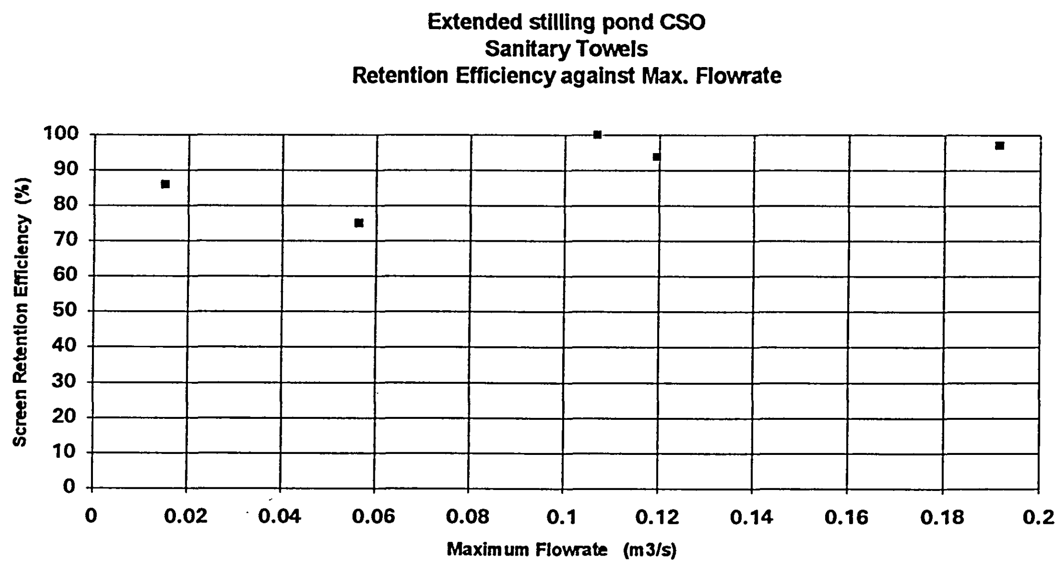

Extended stilling pond CSO
Sanitary Towels
Retention Efficiency against Max. Flowrate
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Maximum Flowrate (m3/s)

Figure 3.85

BOTH CSO SITES

Screen Retention Efficiency against Max. Flowrate

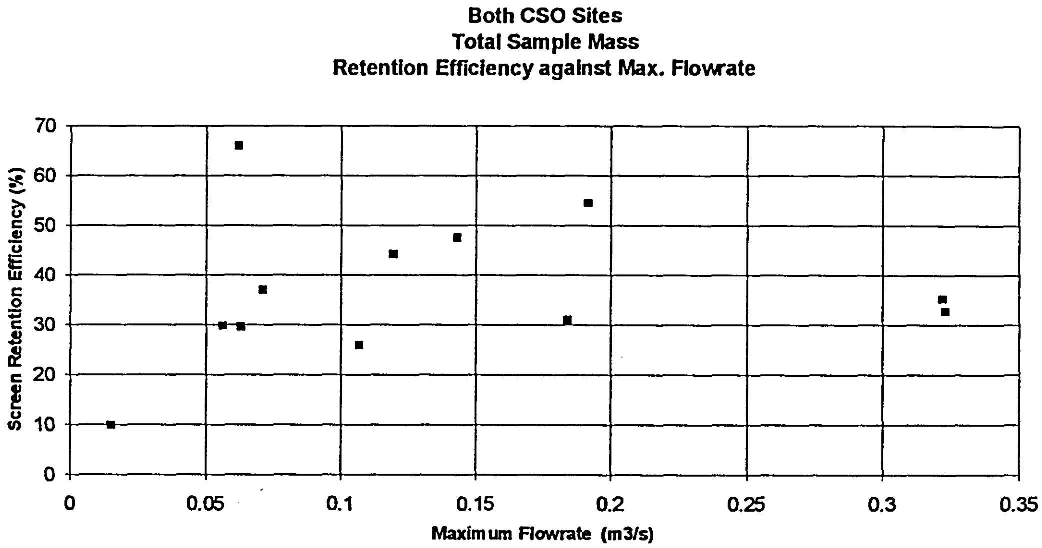


Figure 3.86

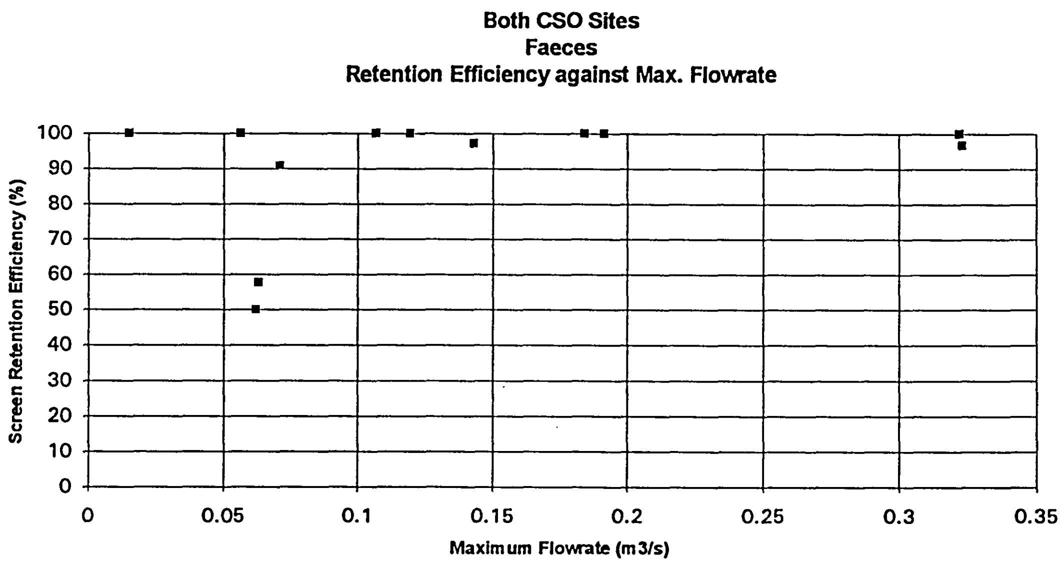


Figure 3.87

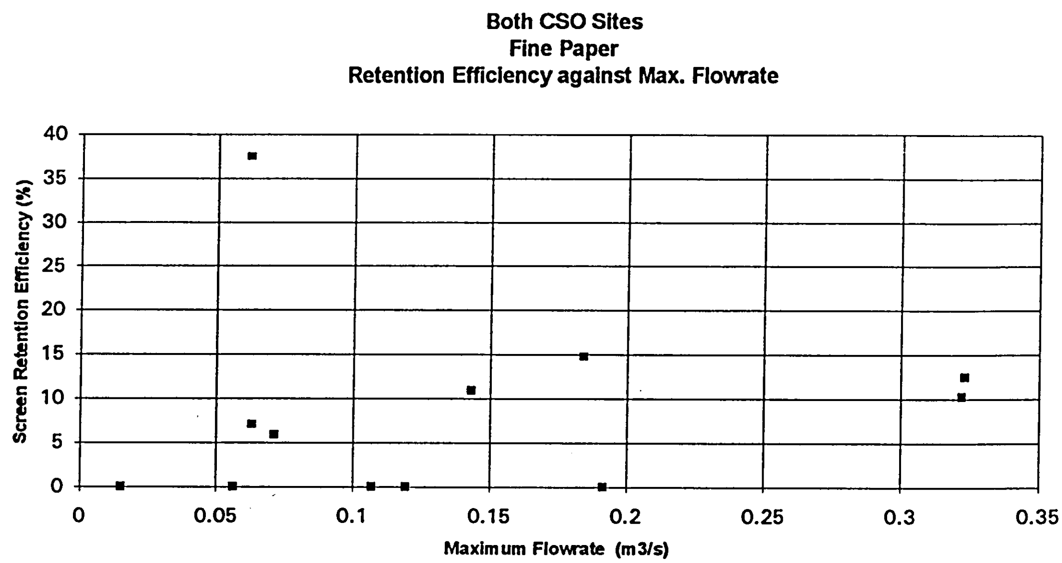


Figure 3.88

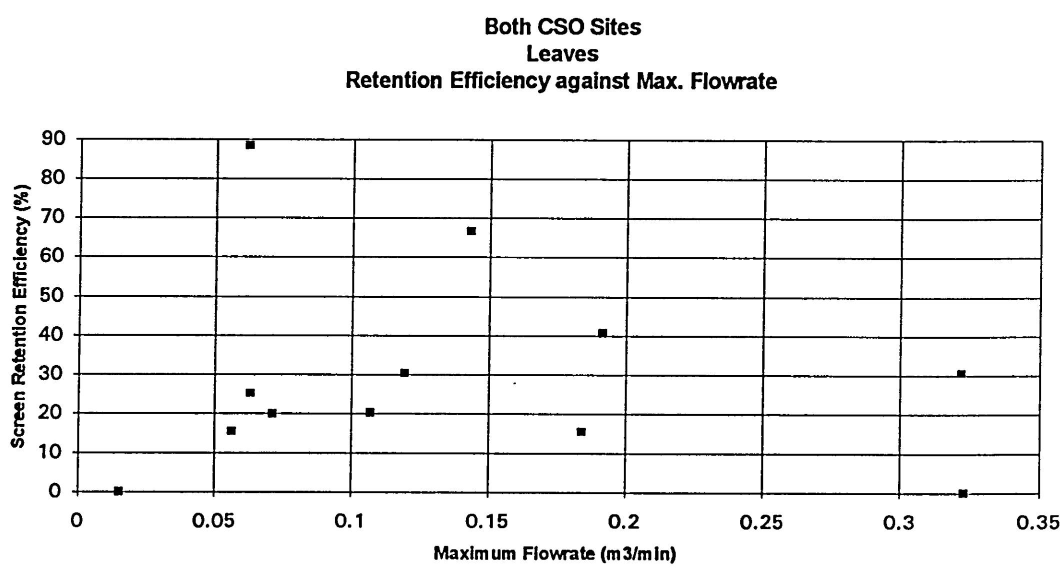


Figure 3.89

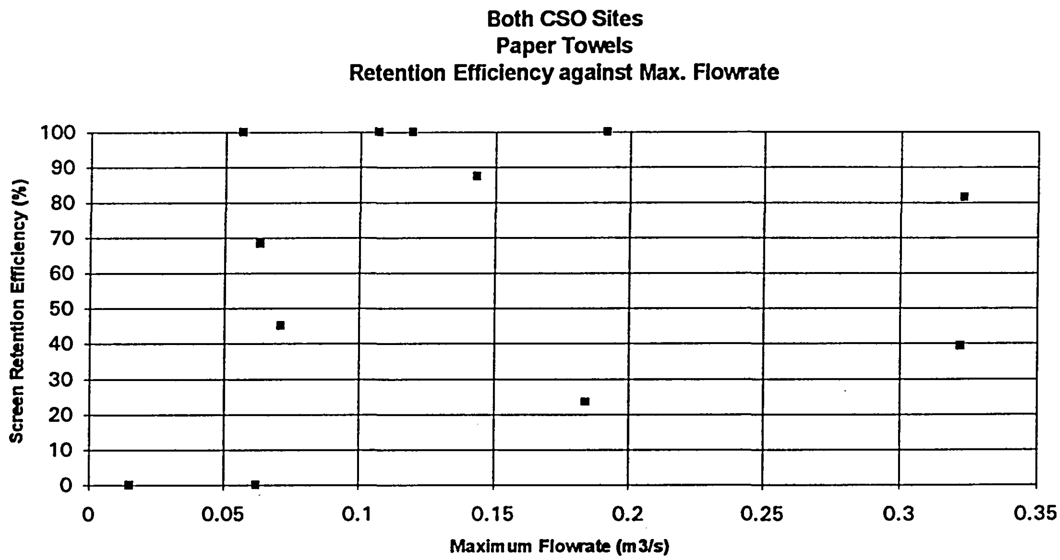


Figure 3.90

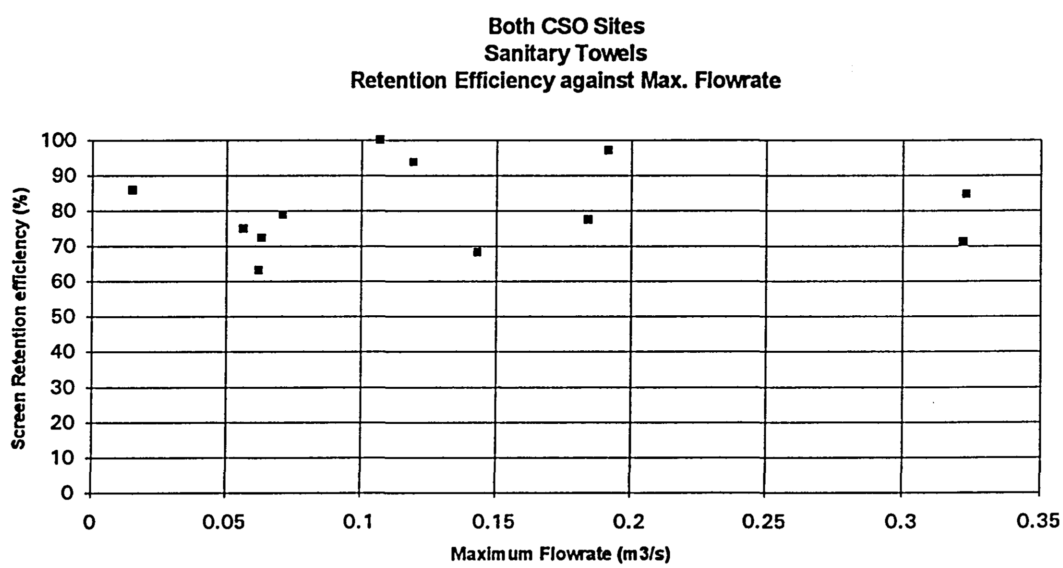


Figure 3.91

Sharpe & Kirkbride Stilling pond CSO

Screen Retention Efficiency against Total Mass presented to Screen

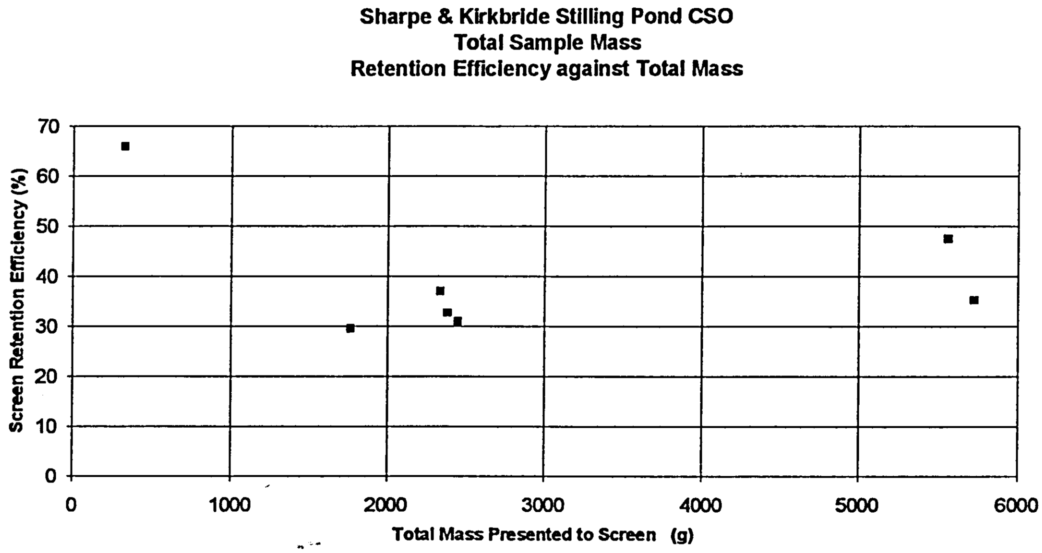


Figure 3.92

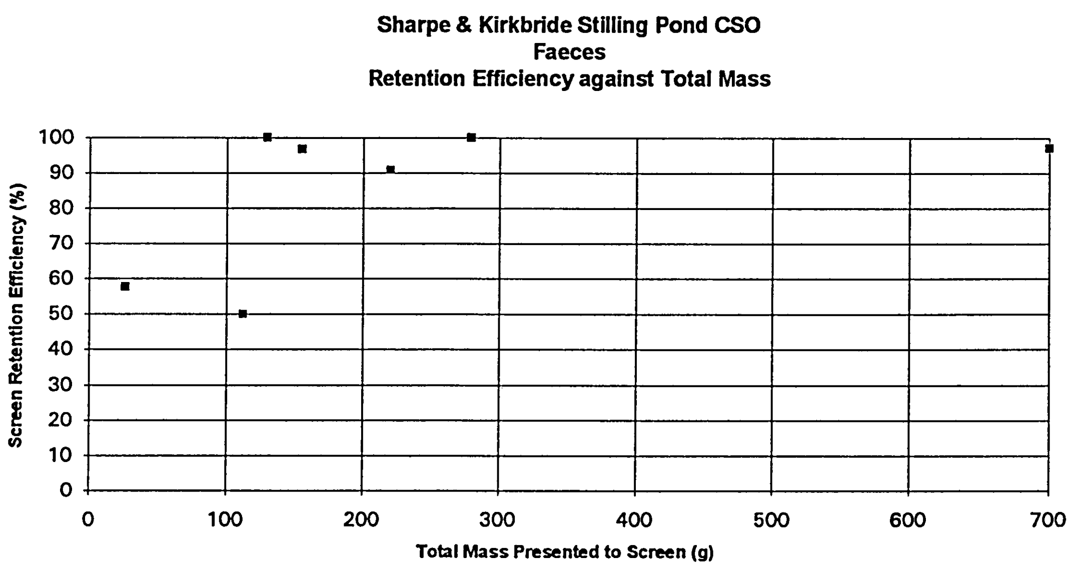


Figure 3.93

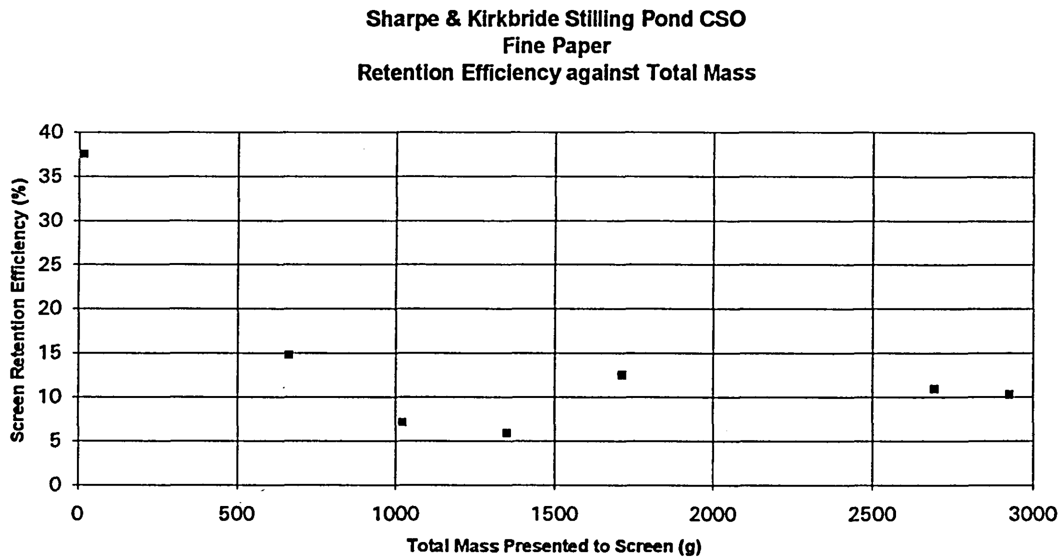


Figure 3.94

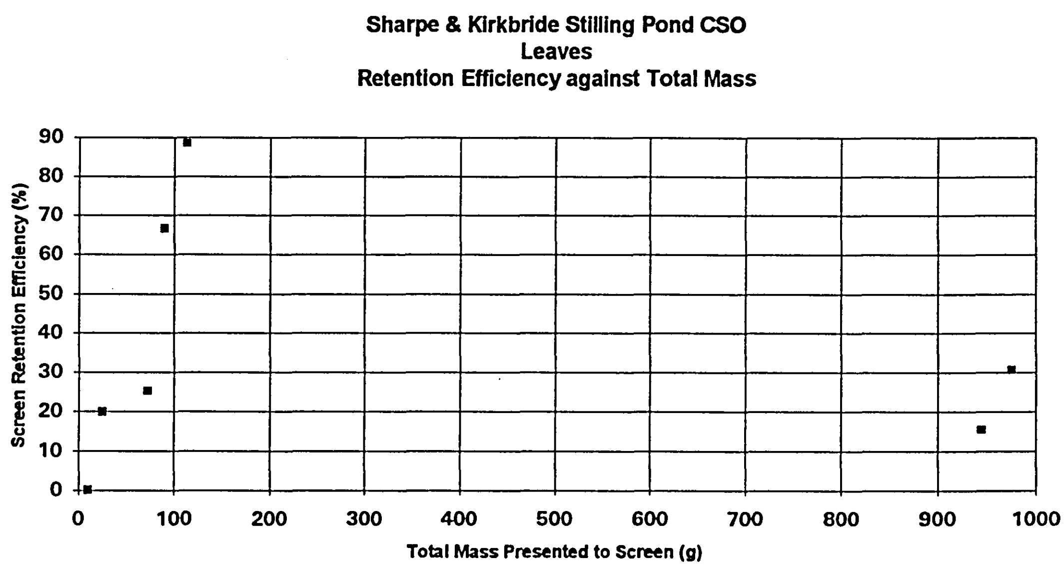


Figure 3.95

Sharpe & Kirkbride Stilling Pond CSO
Paper Towels
Retention Efficiency against Total Mass

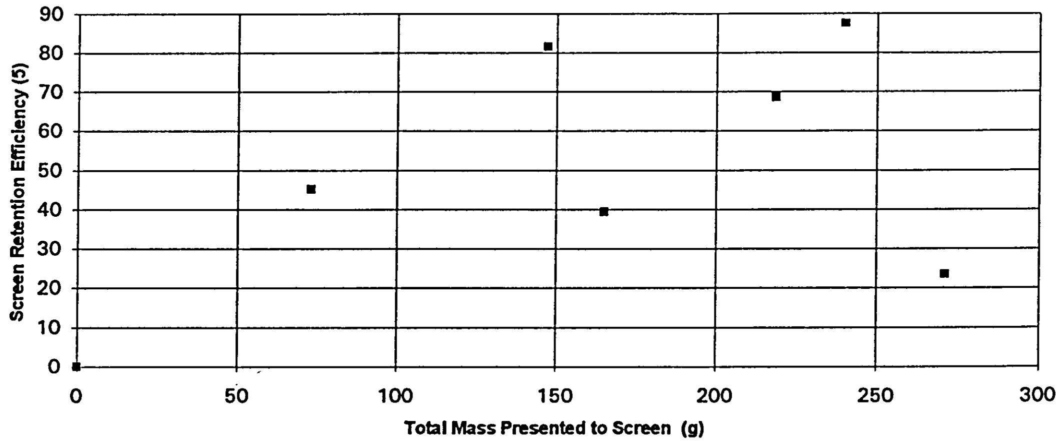


Figure 3.96

Sharpe & Kirkbride Stilling Pond CSO
Sanitary Towels
Retention Efficiency against Total Mass

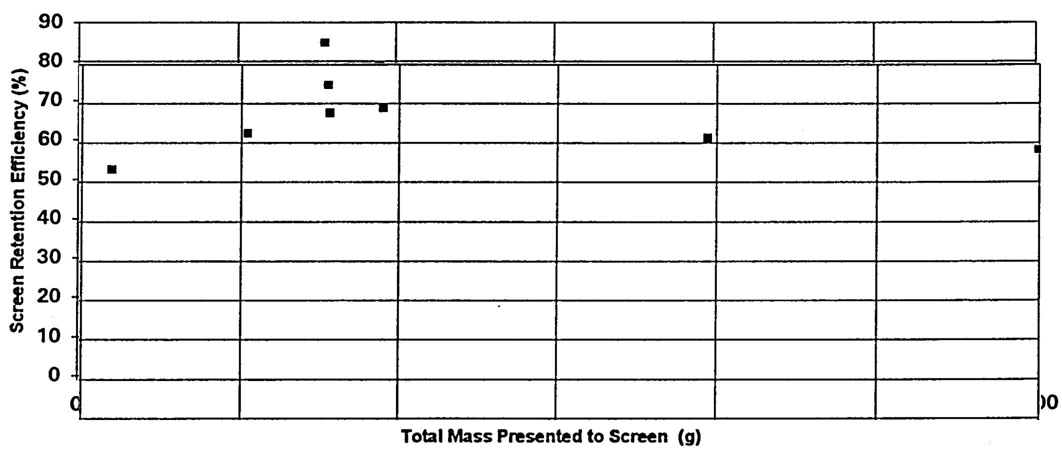


Figure 3.97

Extended Stilling pond CSO

Screen Retention Efficiency against Total Mass presented to Screen

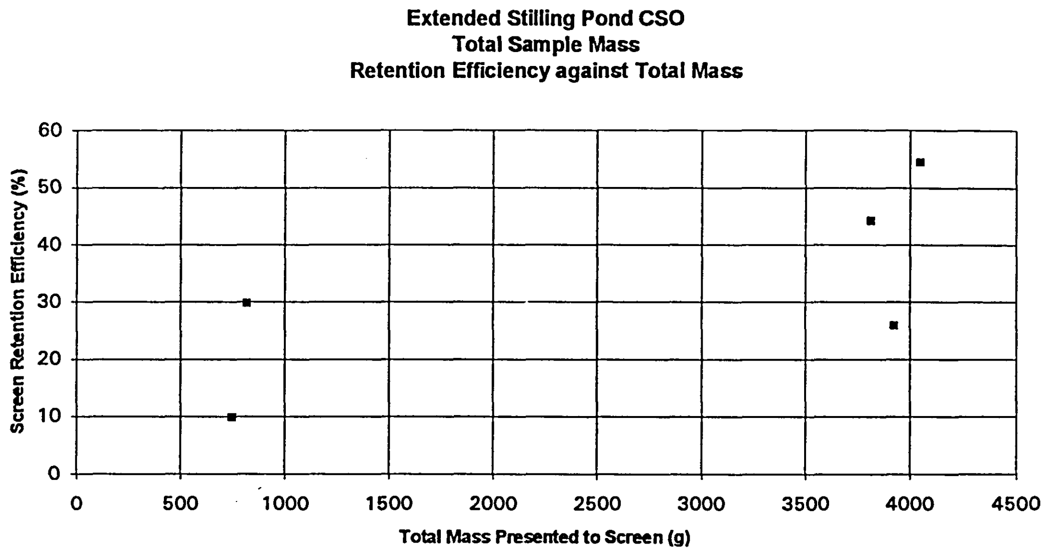


Figure 3.98

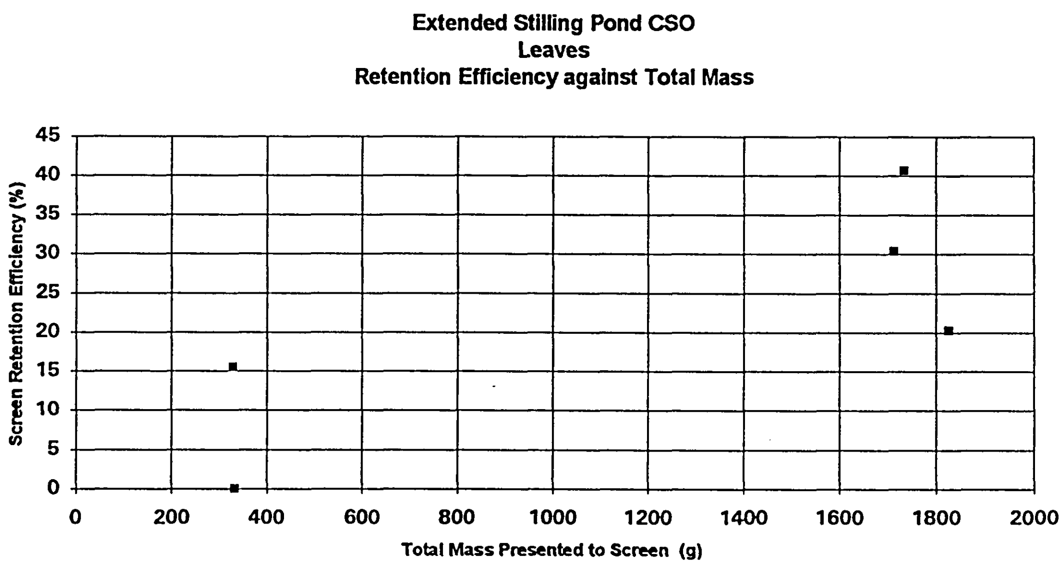


Figure 3.99

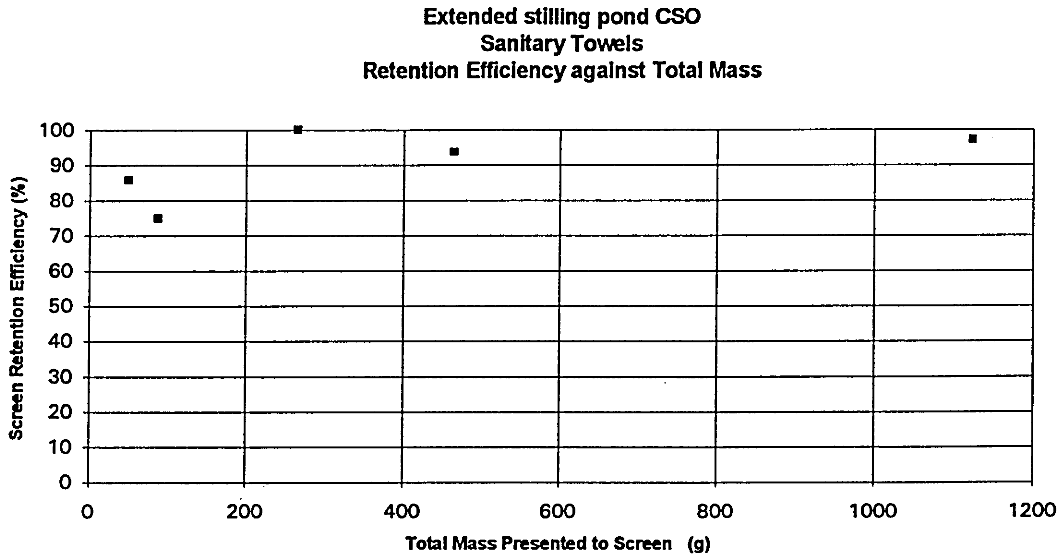

Extended stilling pond CSO
Sanitary Towels
Retention Efficiency against Total Mass
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
Total Mass Presented to Screen (g)

Figure 3.100

BOTH CSO SITES

Screen Retention Efficiency against Total Mass presented to Screen

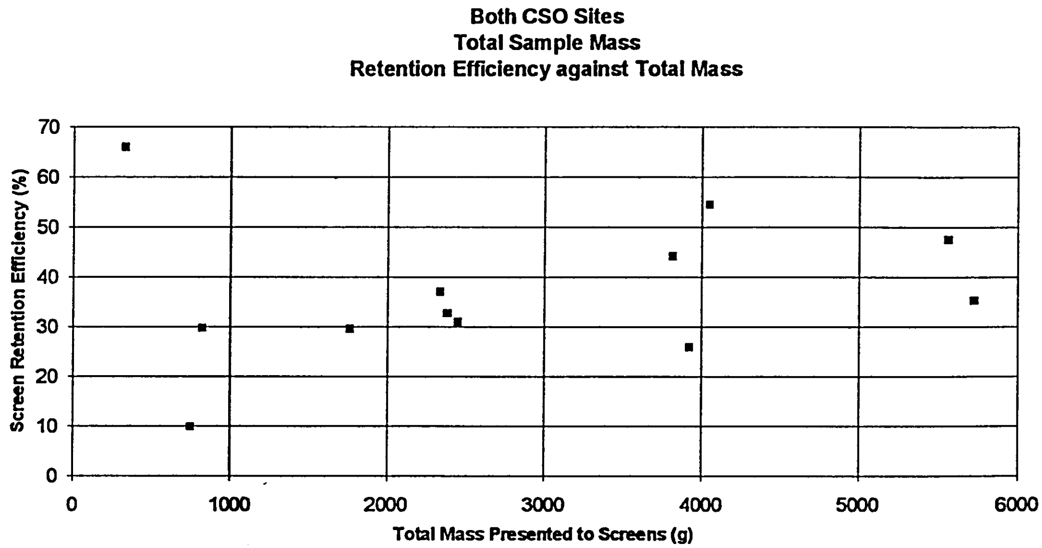


Figure 3.101

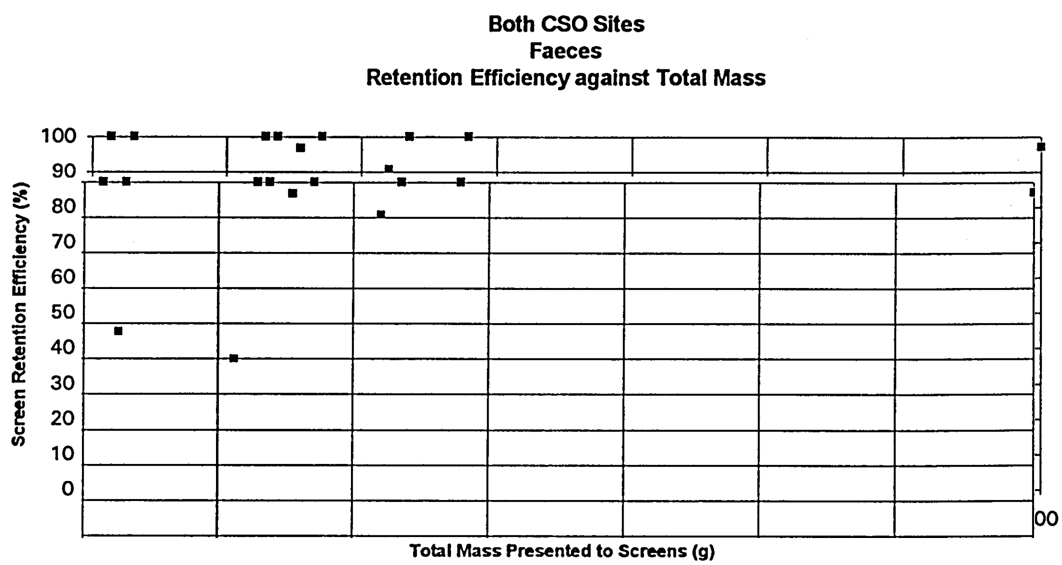


Figure 3.102

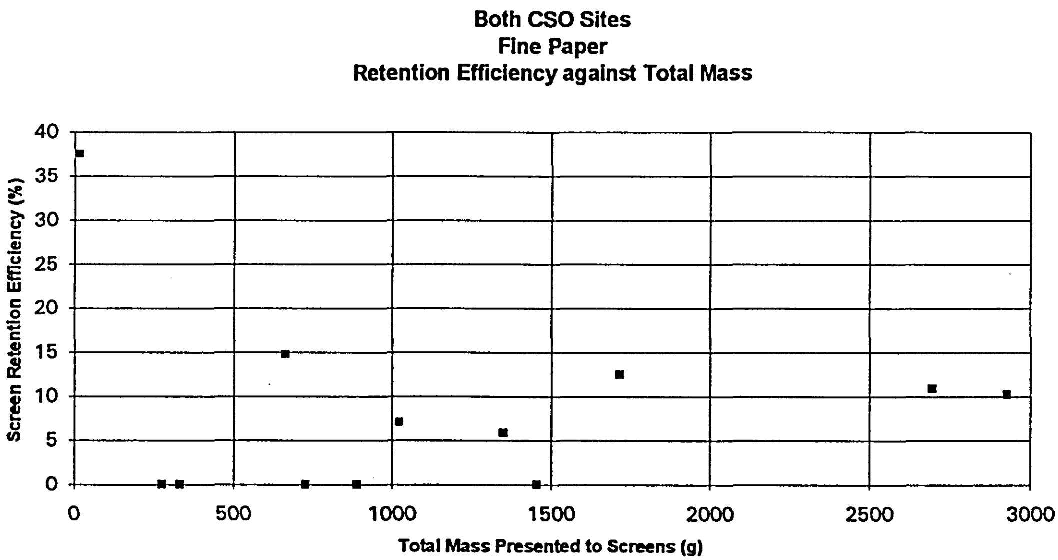


Figure 3.103

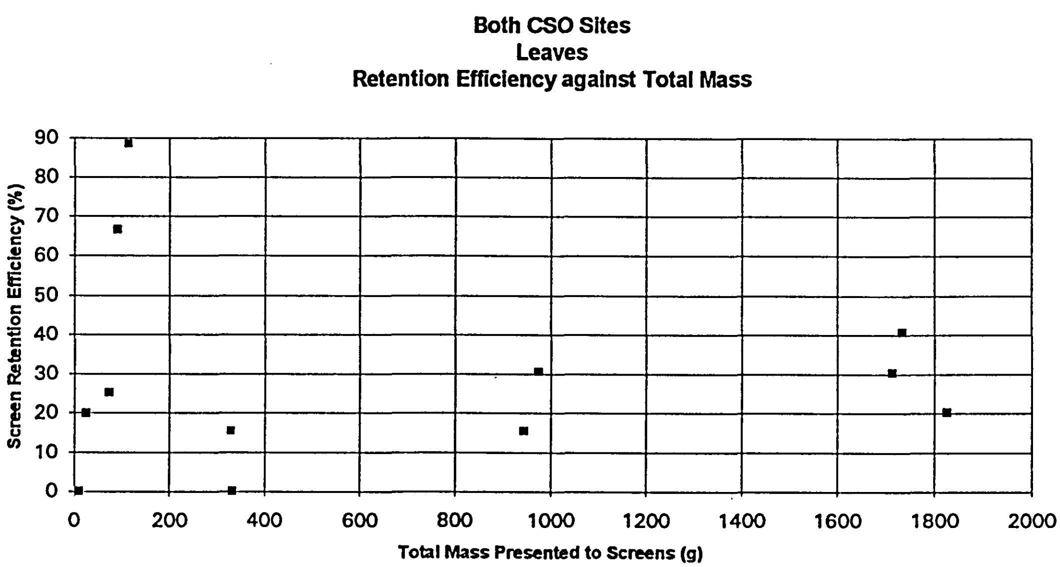


Figure 3.104

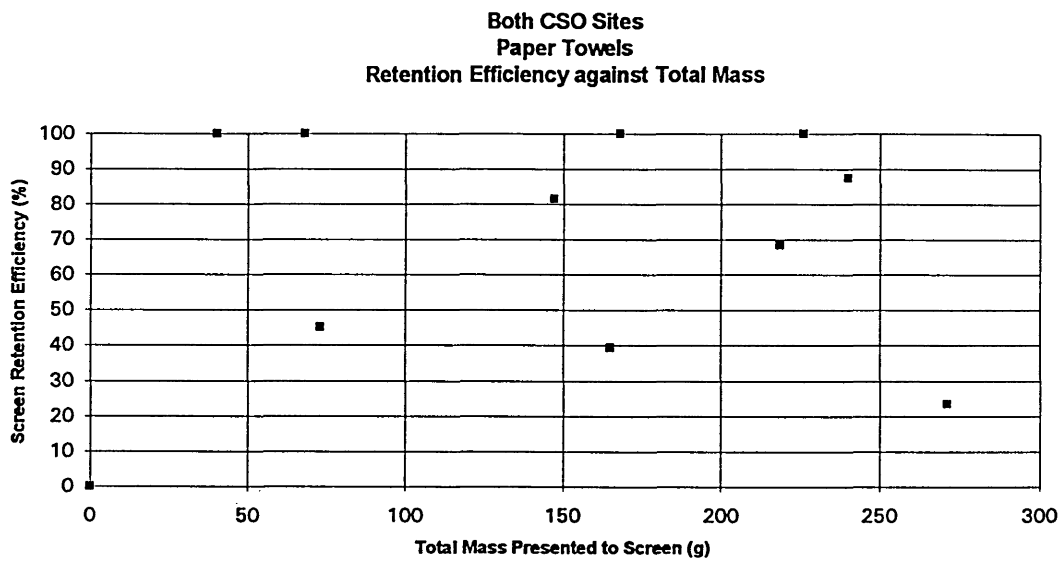


Figure 3.105

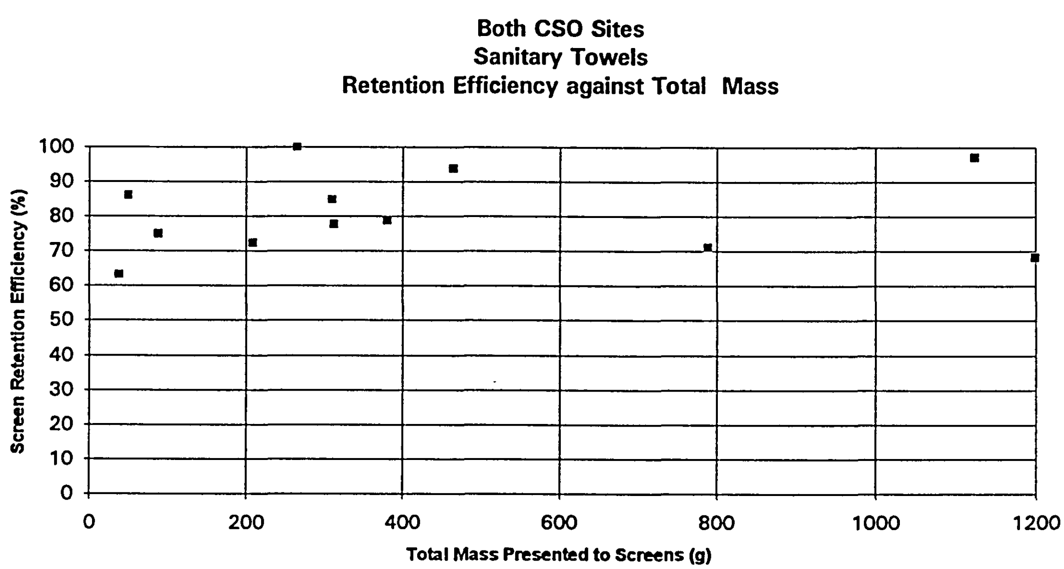


Figure 3.106

Sharpe & Kirkbride Stilling pond CSO

Screen Retention Efficiency against Mean Overflow Intensity

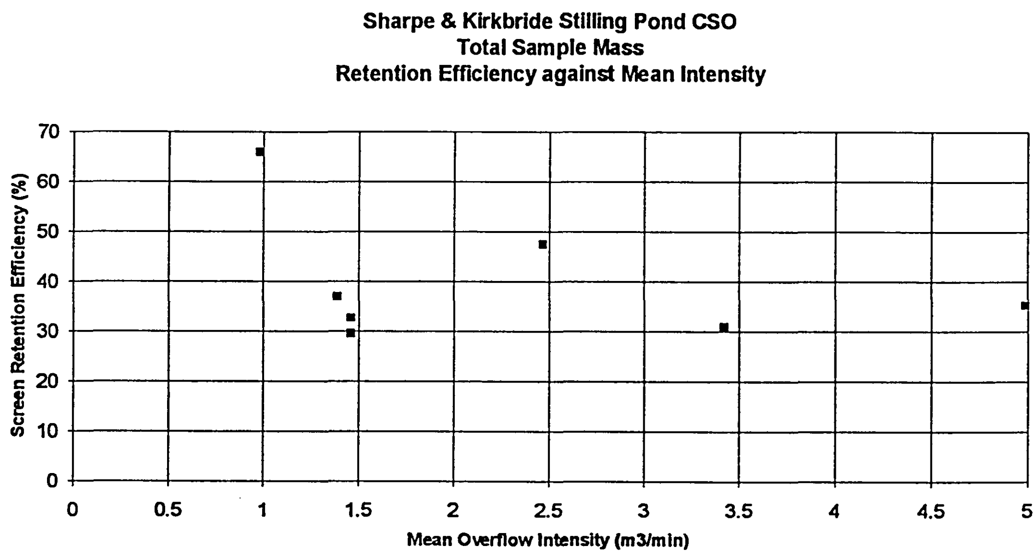


Figure 3.107

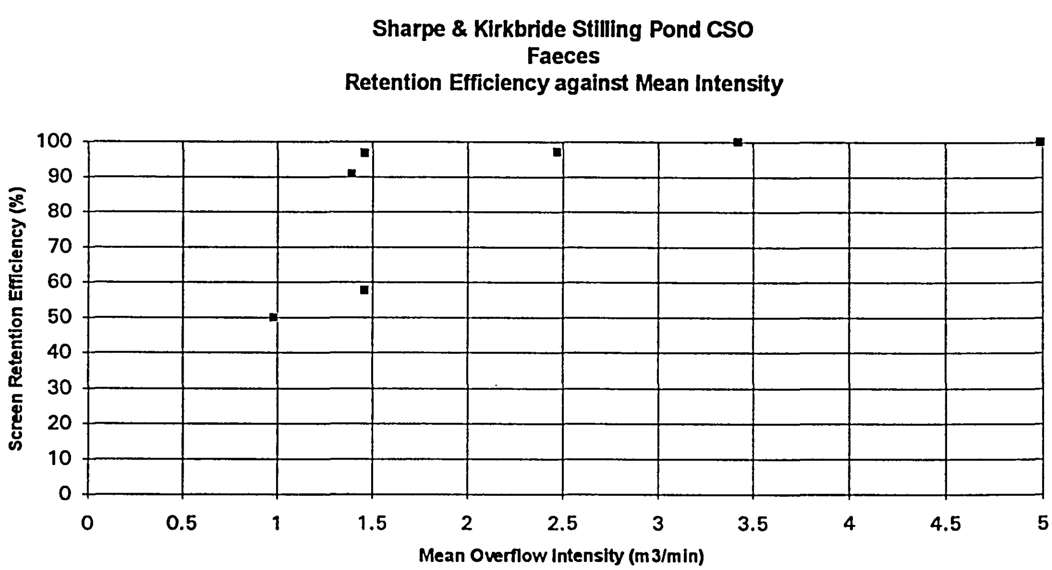


Figure 3.108

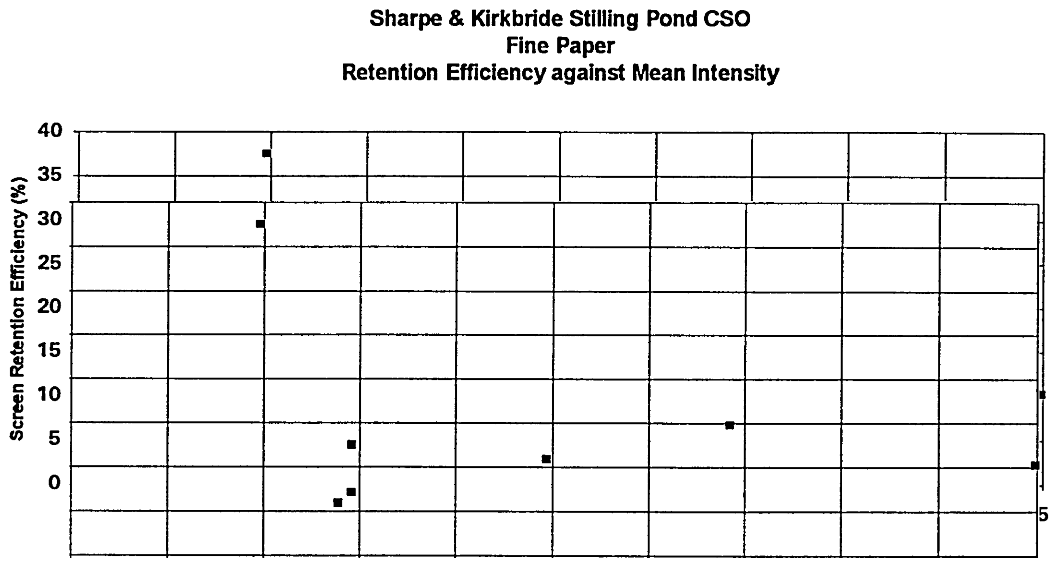


Figure 3.109

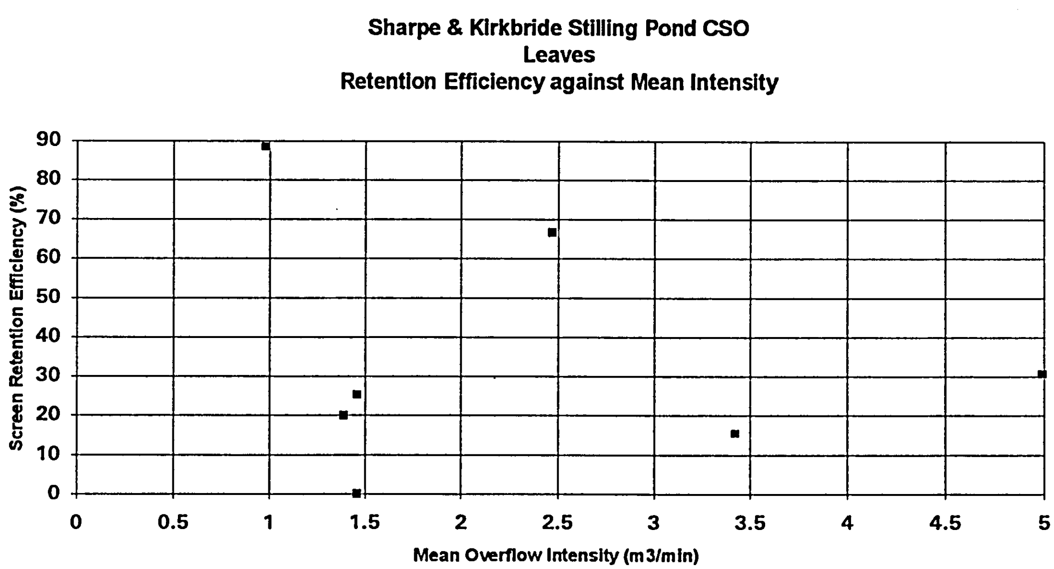


Figure 3.110

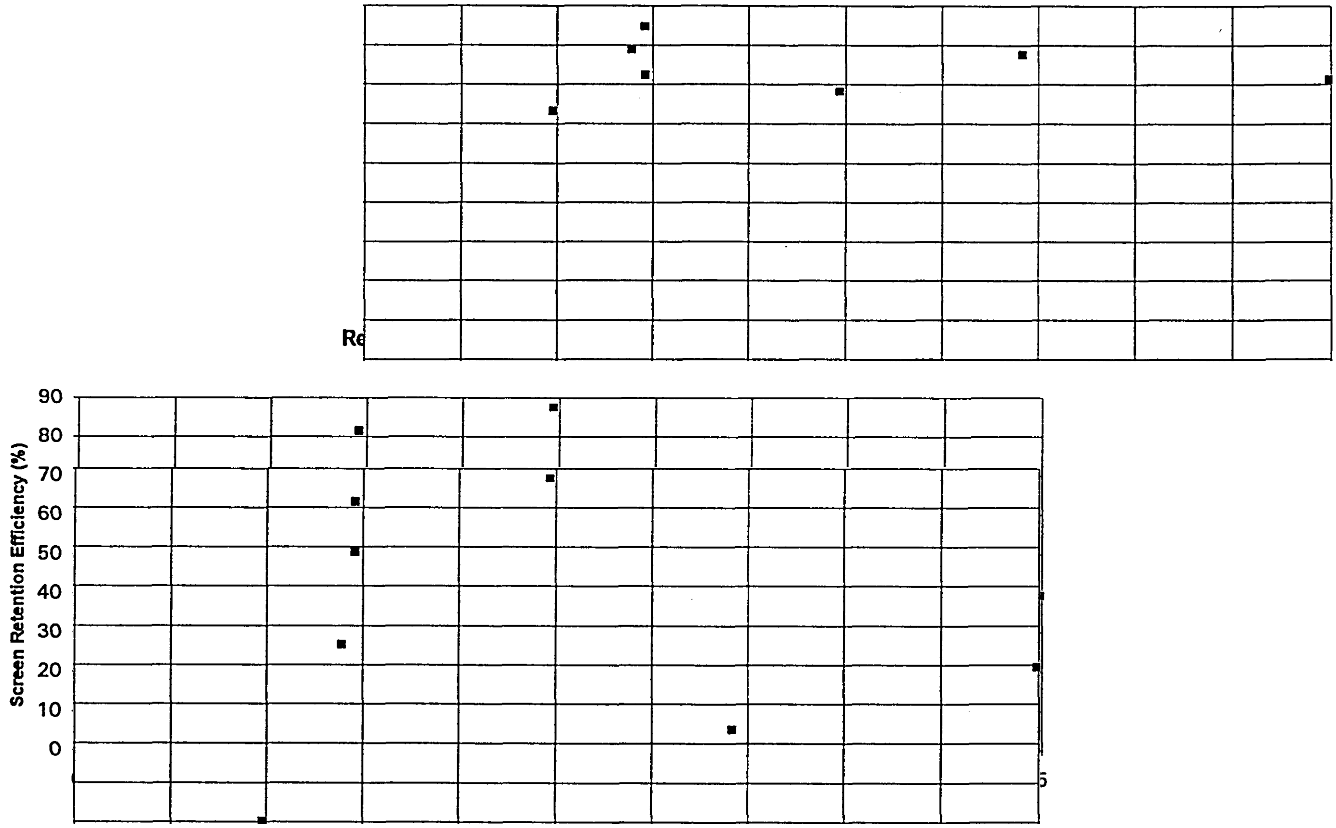


Figure 3.111

Sharpe & Kirkbride Stilling Pond CSO
Sanitary Towels
Retention Efficiency against Mean Intensity

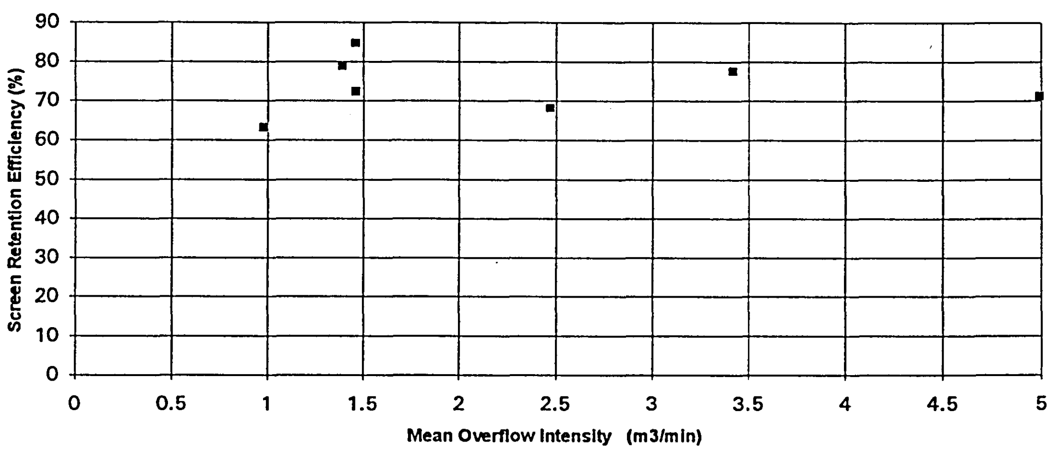


Figure 3.112

Extended Stilling pond CSO

Screen Retention Efficiency against Mean Overflow Intensity

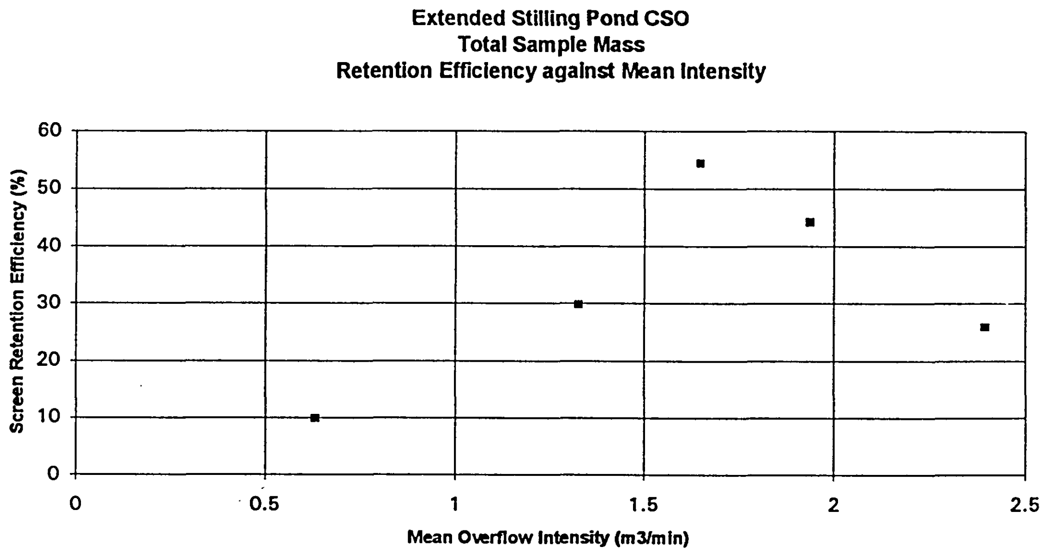


Figure 3.113

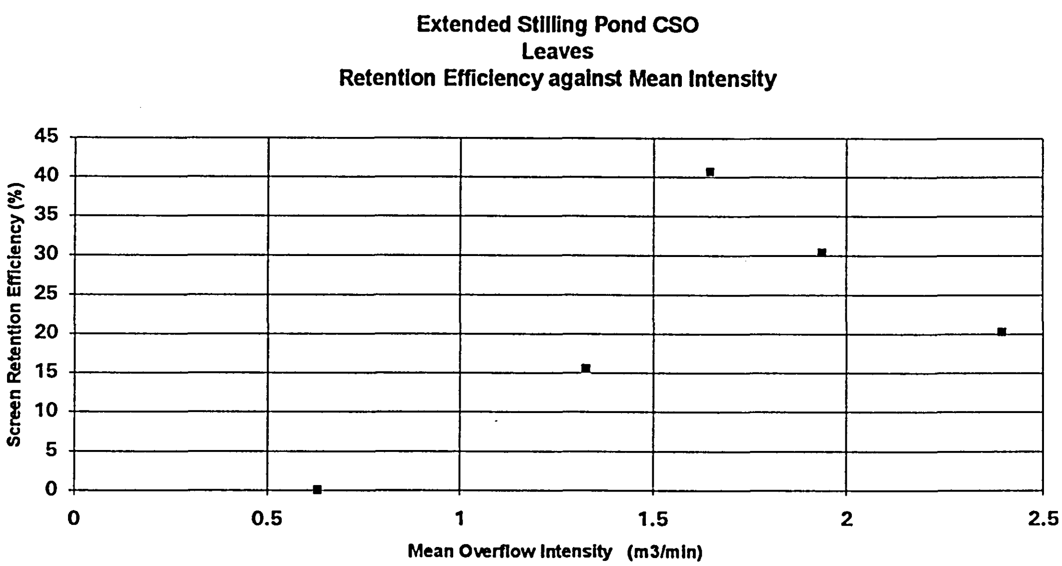


Figure 3.114

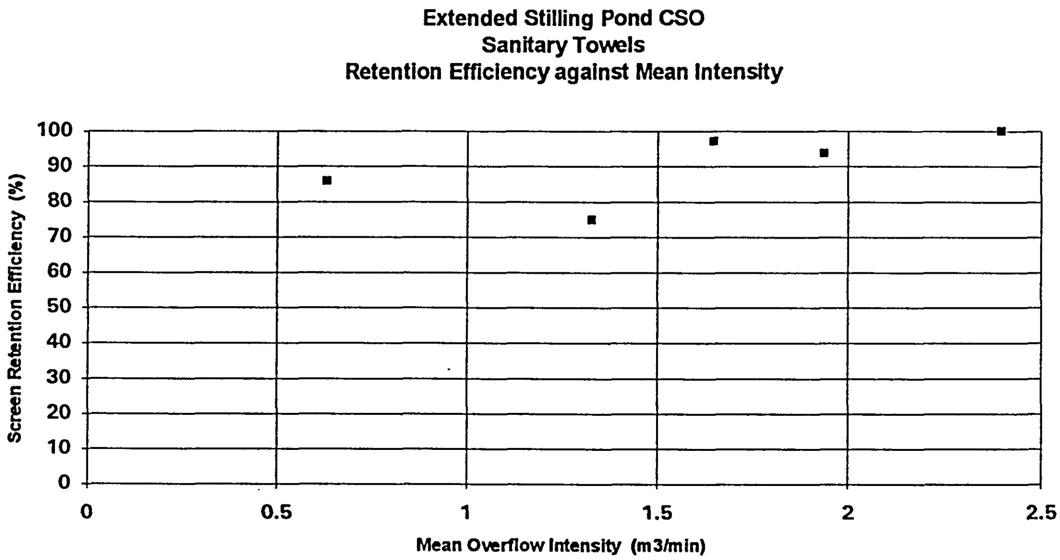

Extended Stilling Pond CSO
Sanitary Towels
Retention Efficiency against Mean Intensity
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
Mean Overflow Intensity (m3/min)

Figure 3.115

BOTH CSO SITES

Screen Retention Efficiency against Mean Intensity

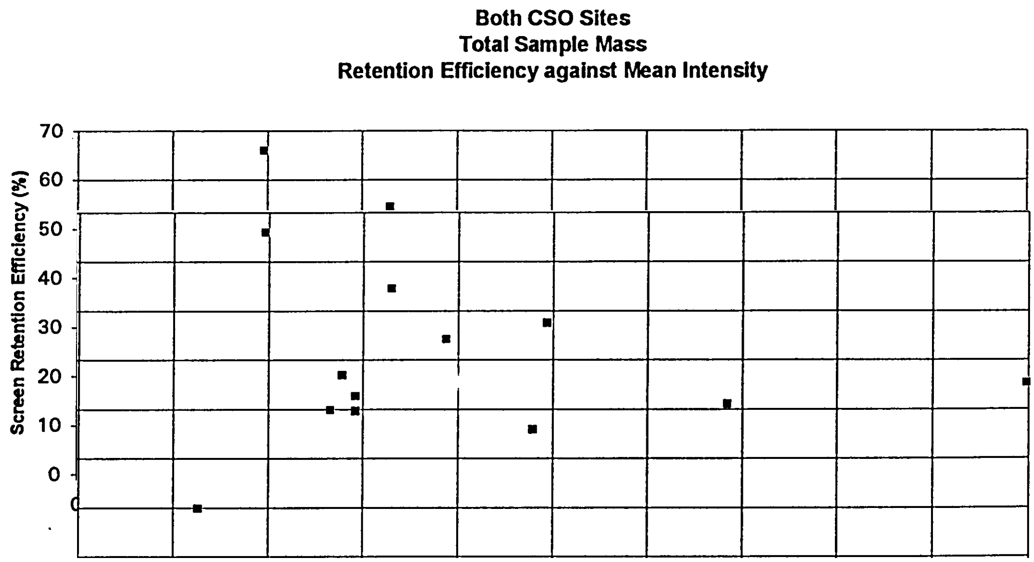


Figure 3.116

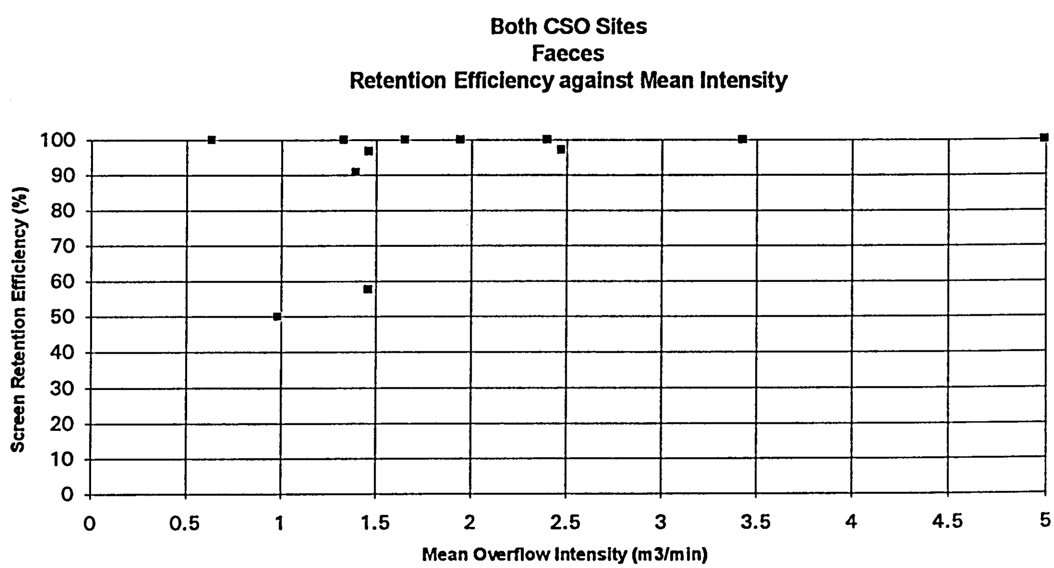


Figure 3.117

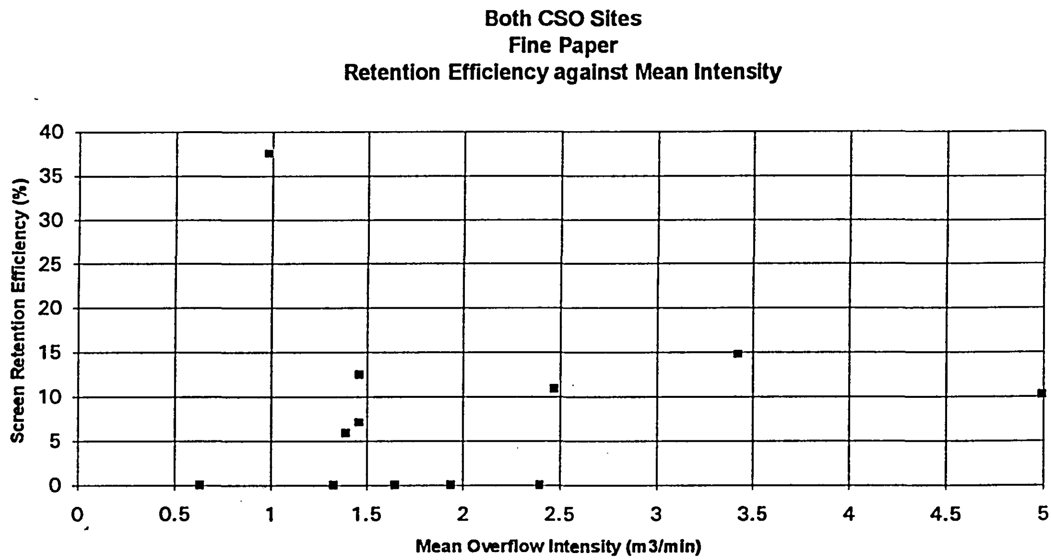


Figure 3.118

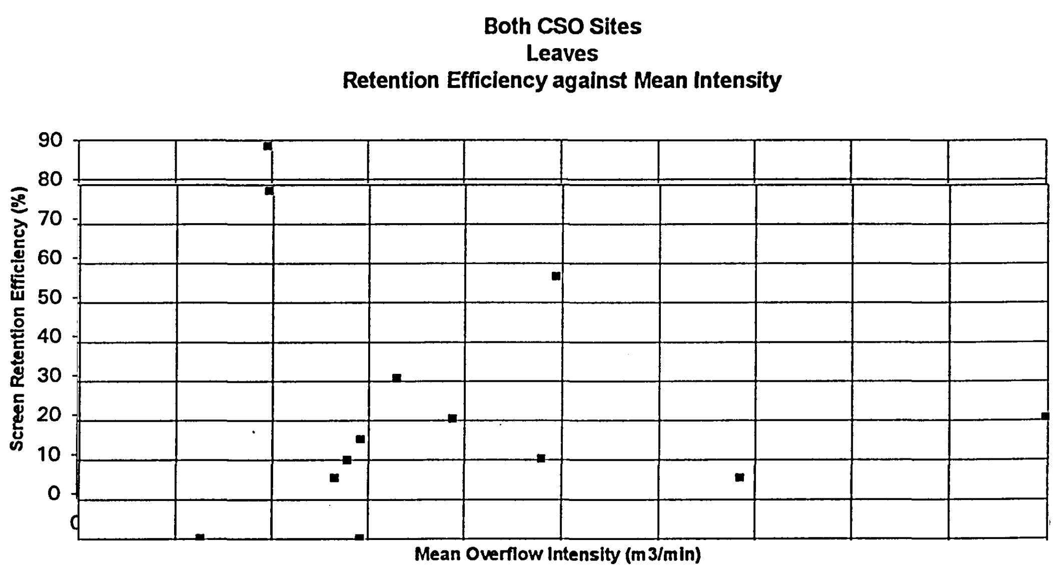


Figure 3.119

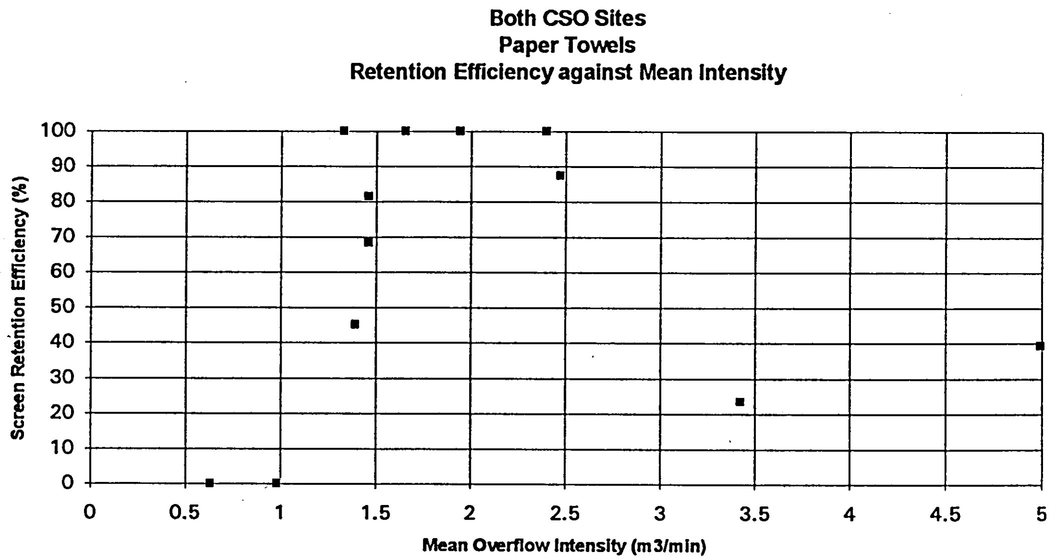


Figure 3.120

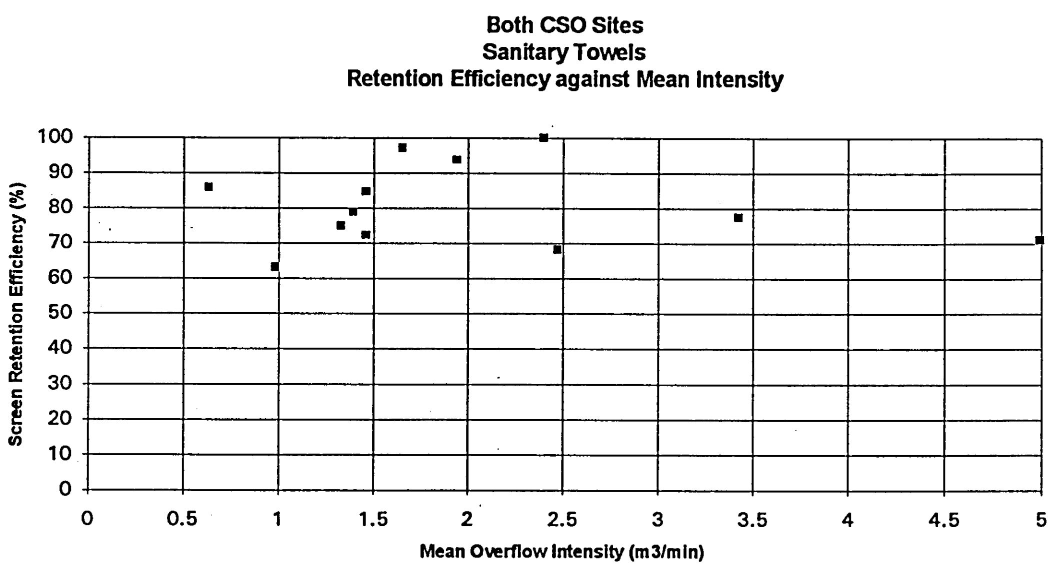


Figure 3.121

Sharpe & Kirkbride Stilling pond CSO

Total Mass presented to Screen against Max. Flowrate

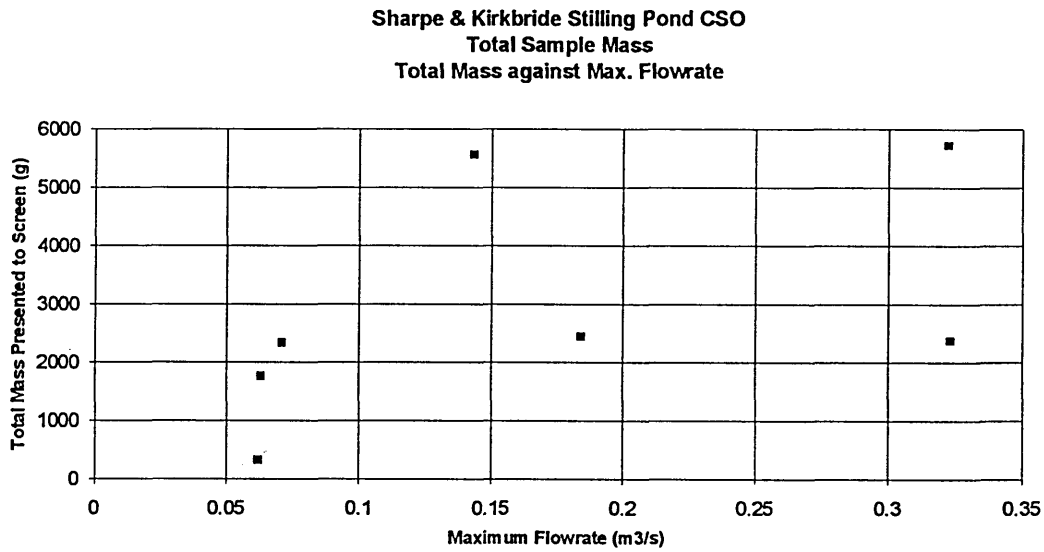


Figure 3.122

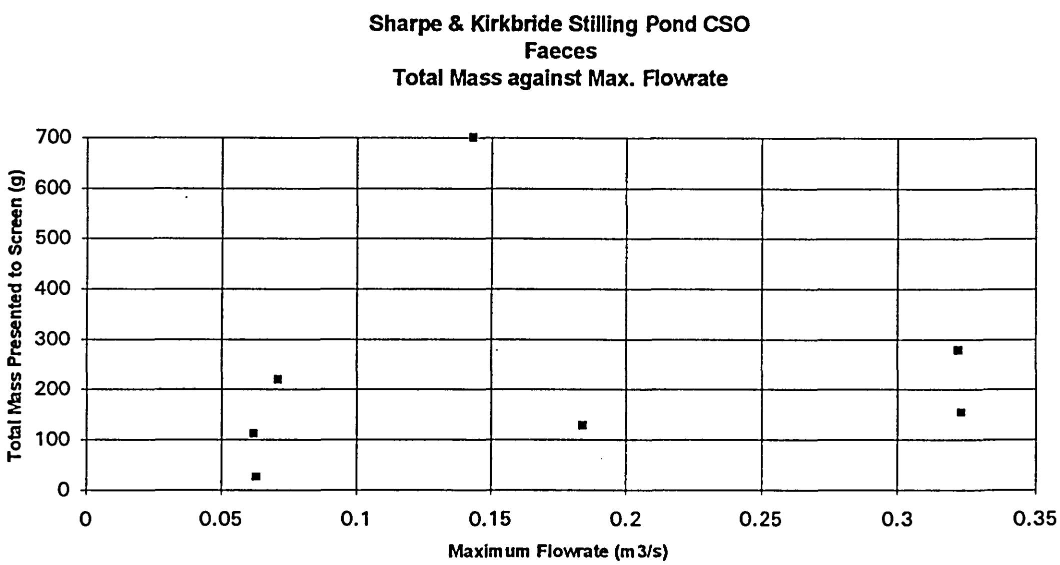


Figure 3.123

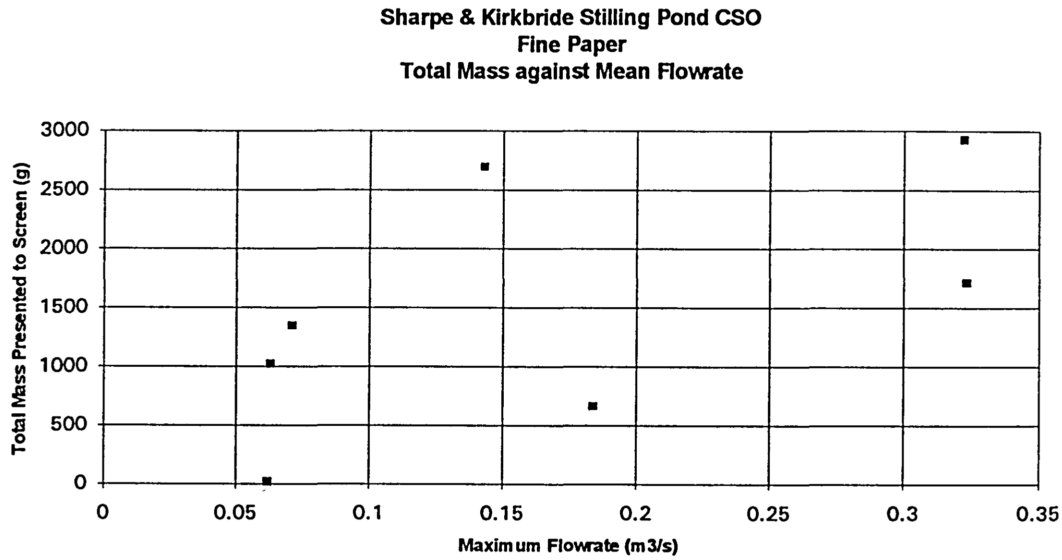


Figure 3.124

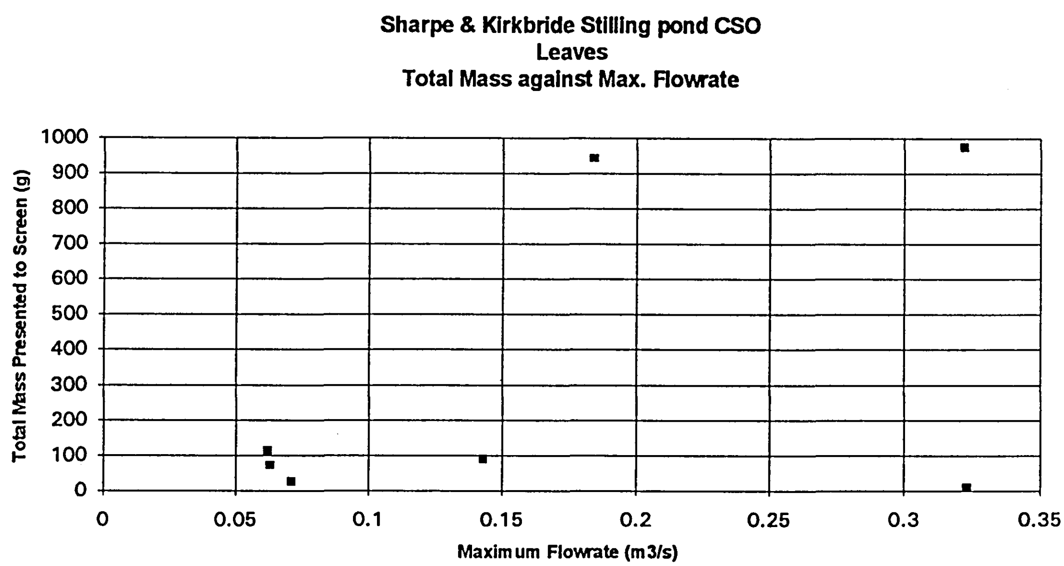


Figure 3.125

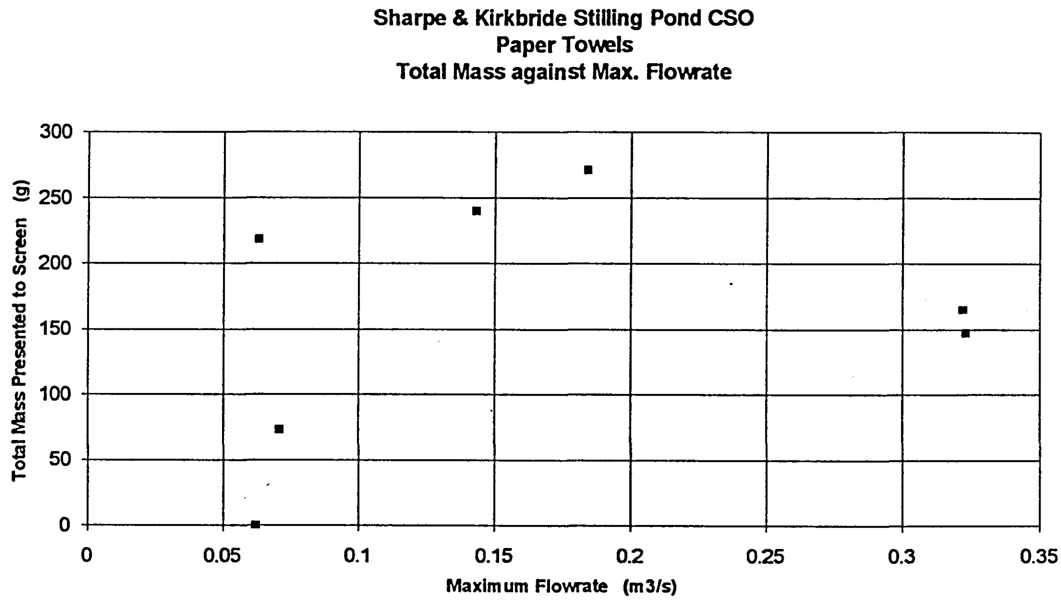


Figure 3.126

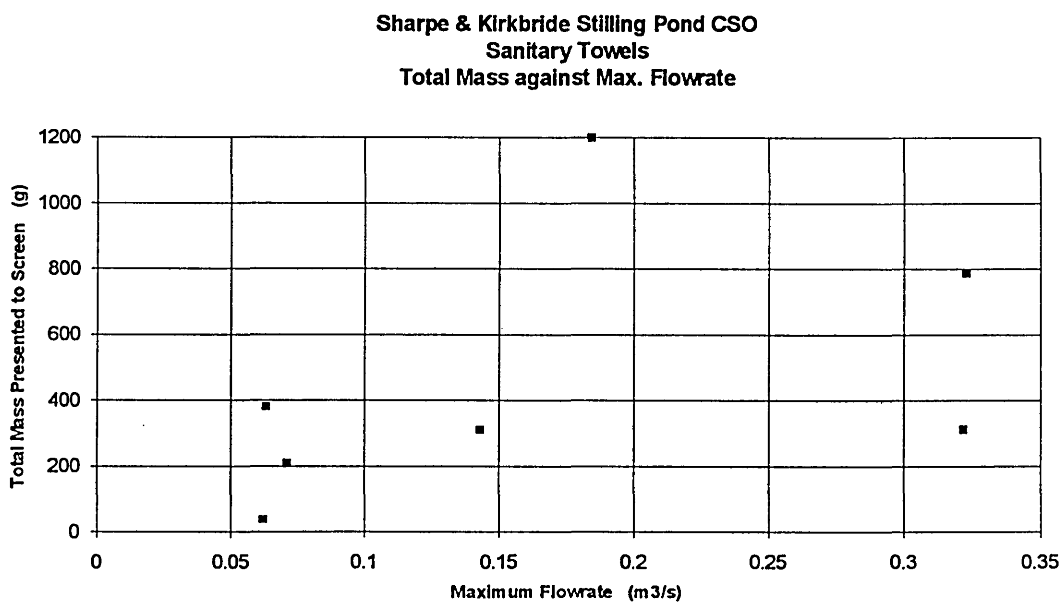


Figure 3.127

Extended Stilling pond CSO

Total Mass presented to Screen against Max. Flowrate

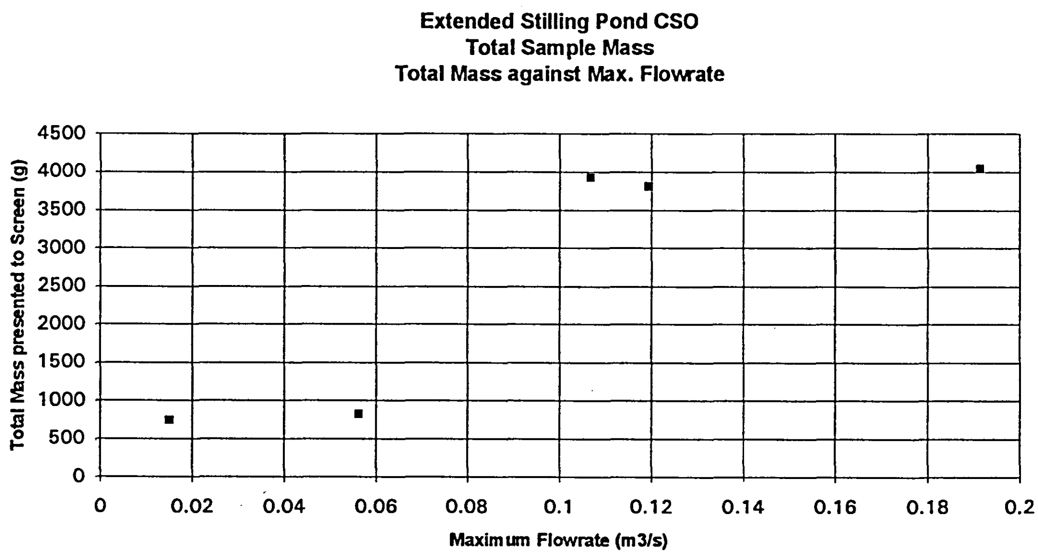


Figure 3.128

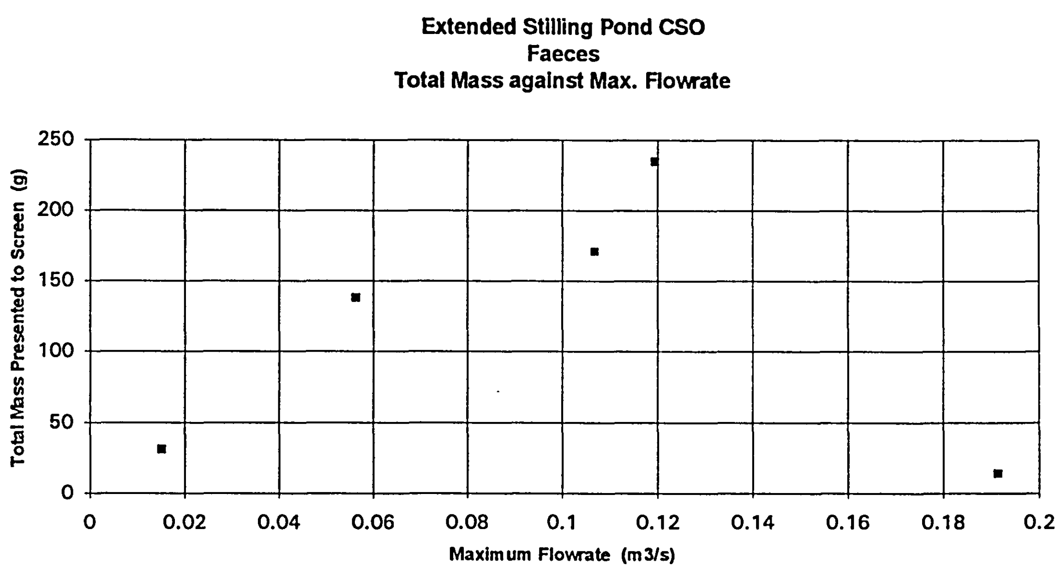


Figure 3.129

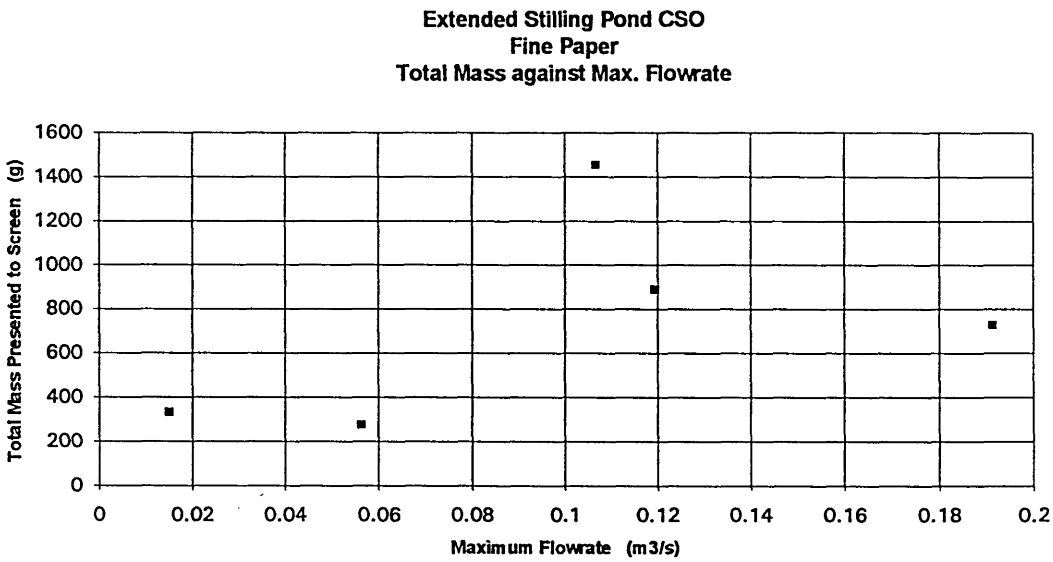


Figure 3.130

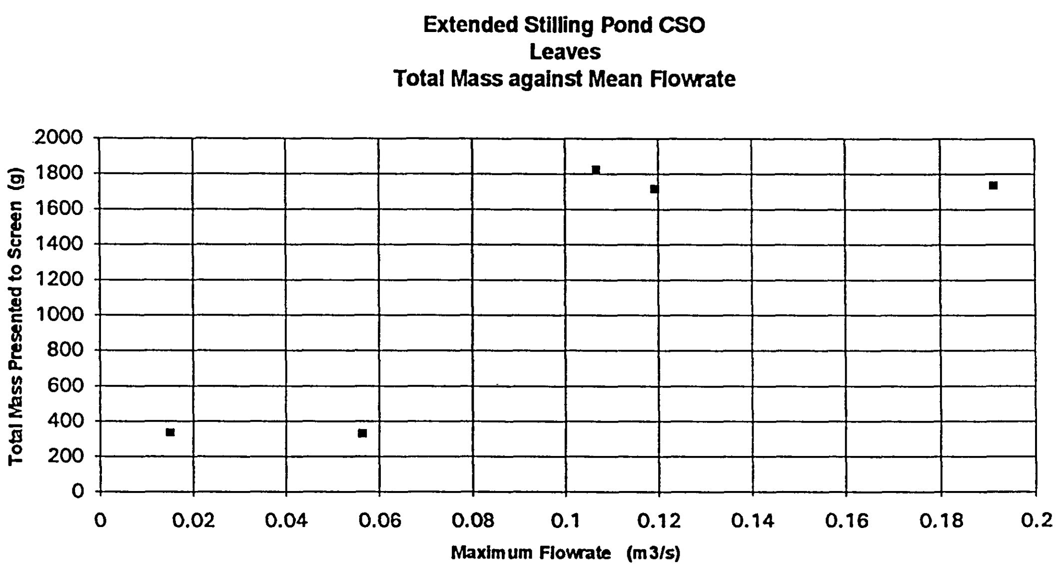


Figure 3.131

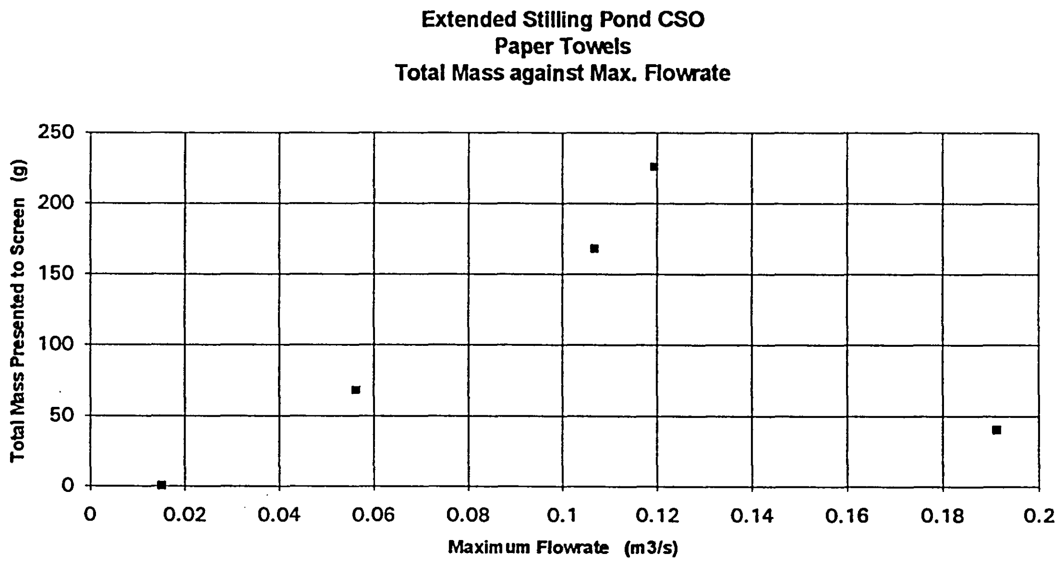


Figure 3.132

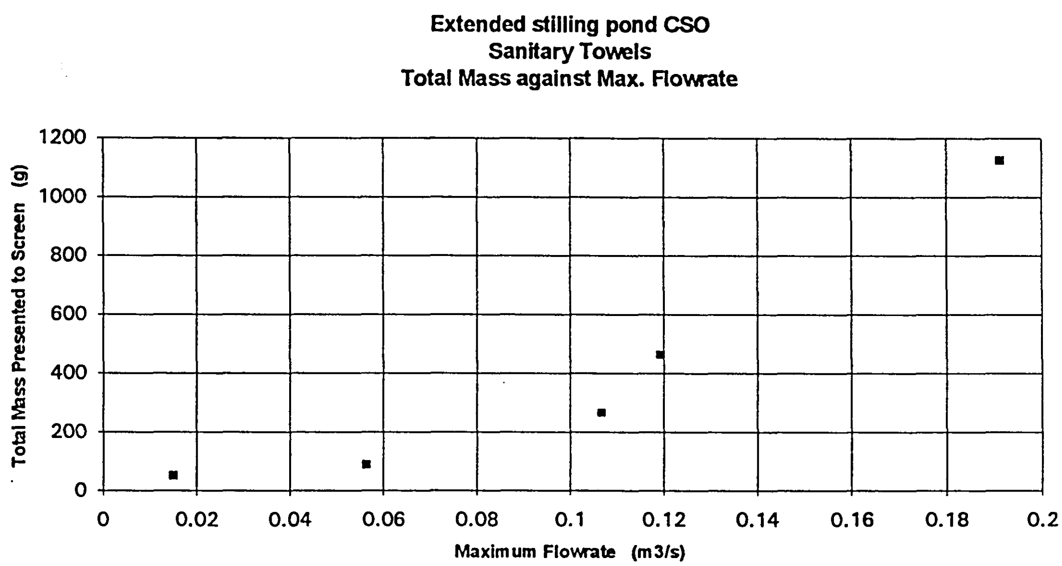


Figure 3.133

BOTH CSO SITES

Total Mass presented to Screen against Max. Flowrate

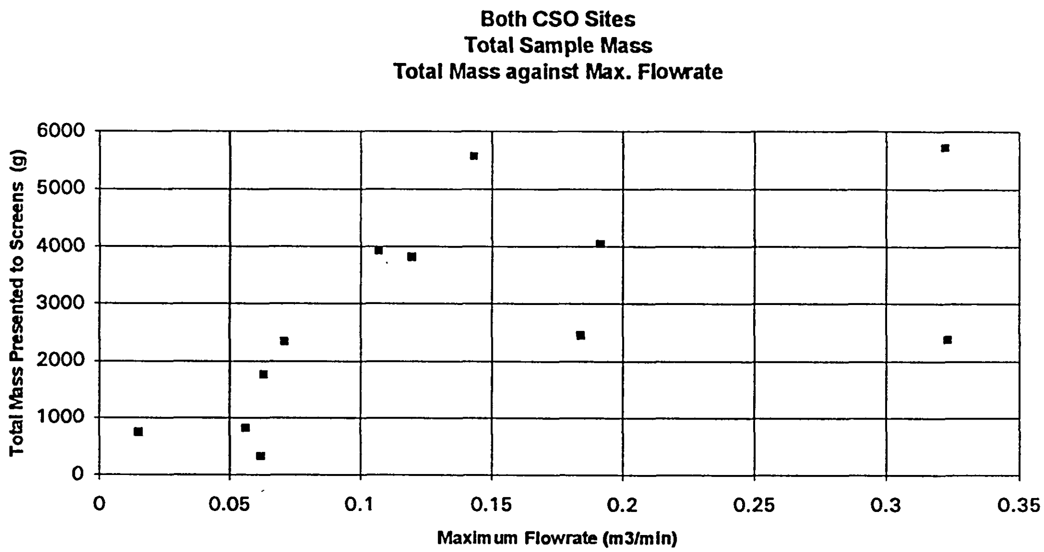


Figure 3.134

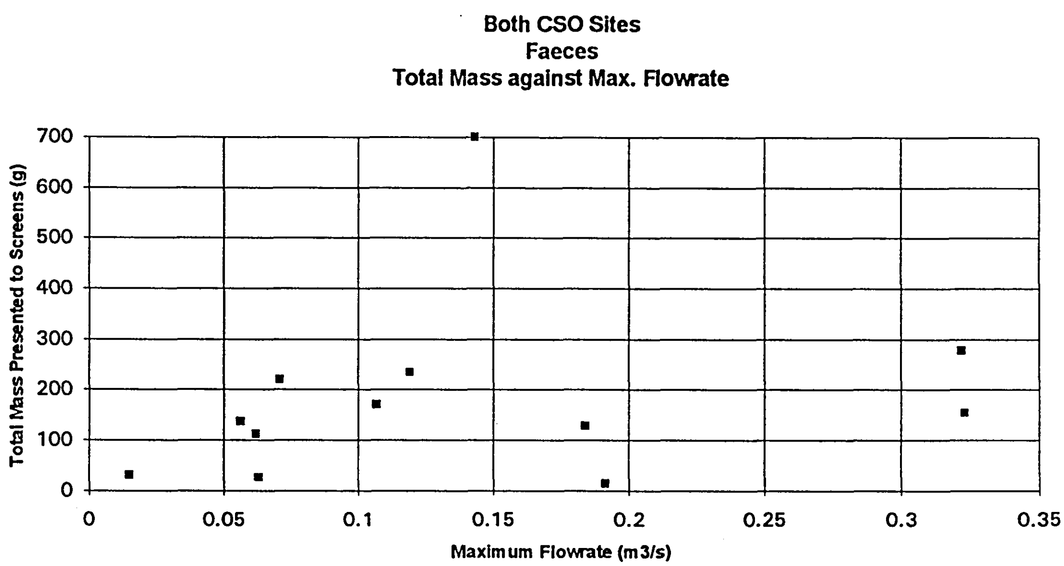


Figure 3.135

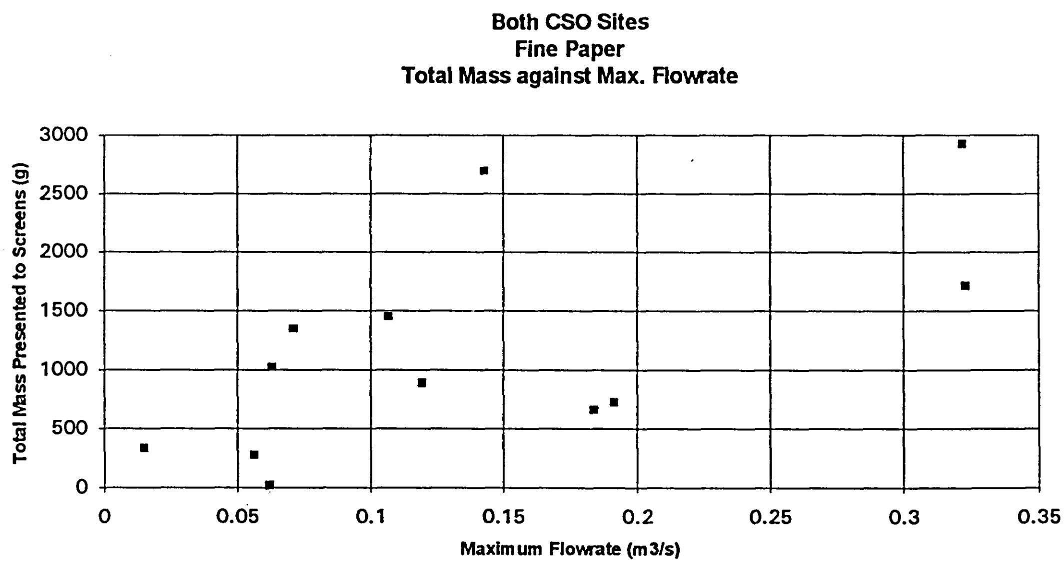


Figure 3.136

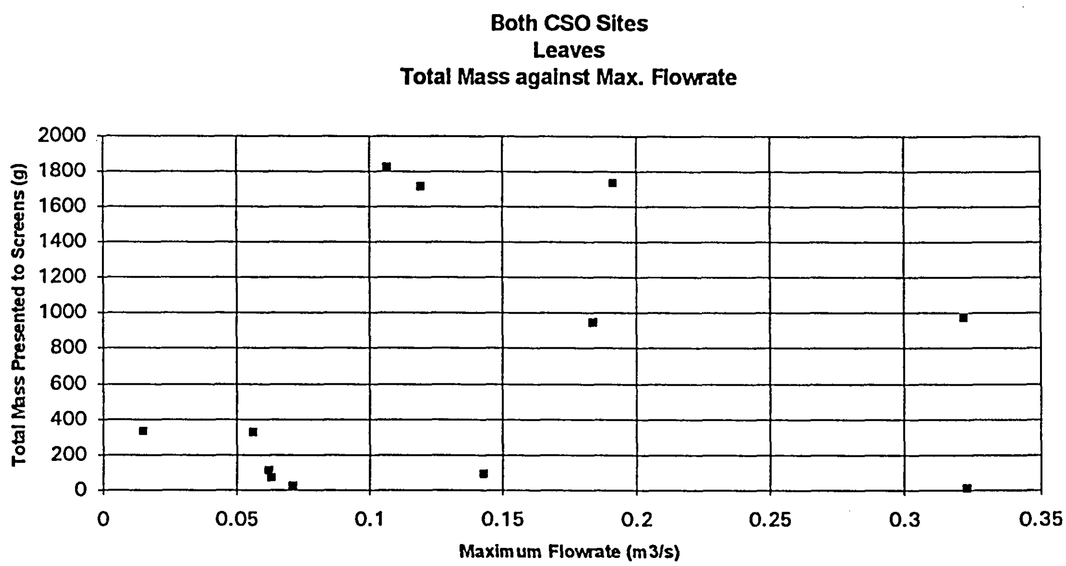


Figure 3.137

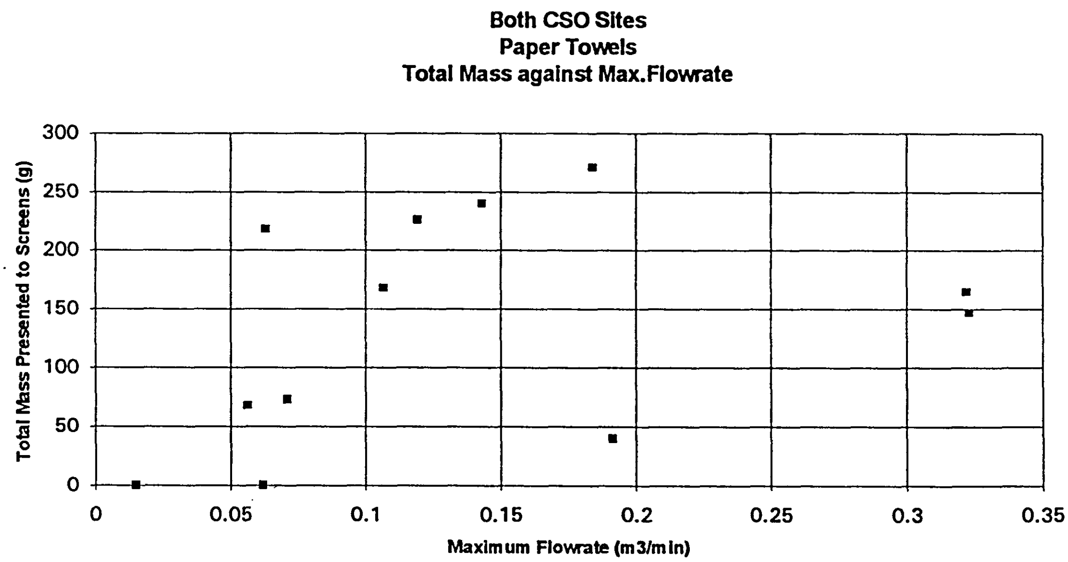


Figure 3.138

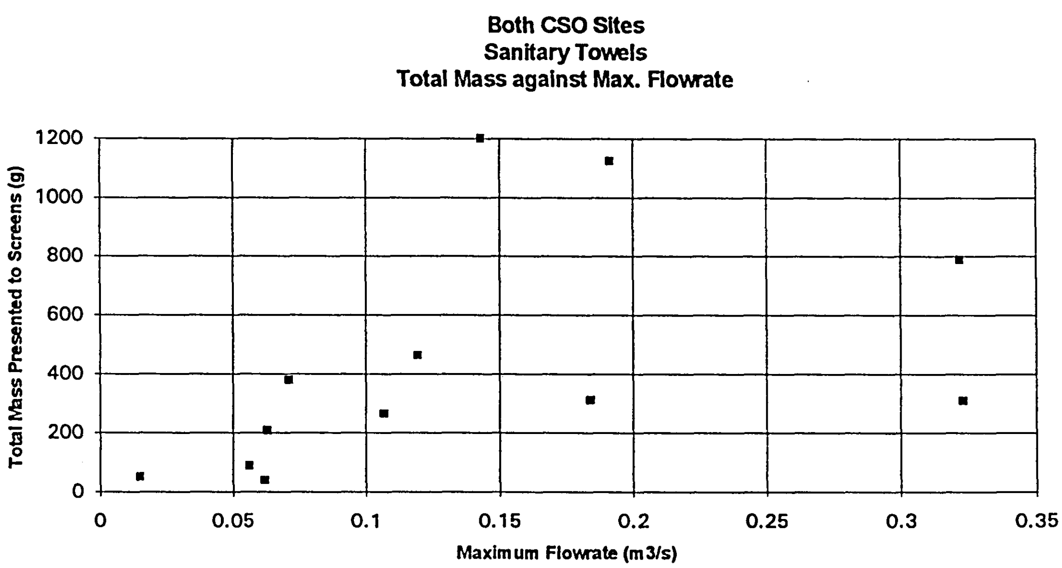


Figure 3.139

Sharpe & Kirkbride Stilling pond CSO

Total Mass presented to Screen against Mean Overflow Intensity

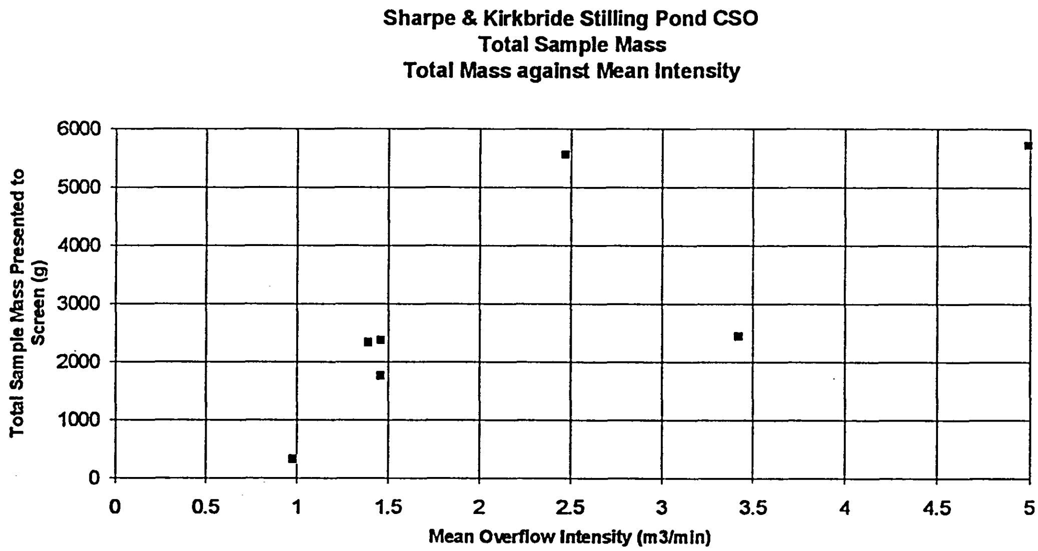


Figure 3.140

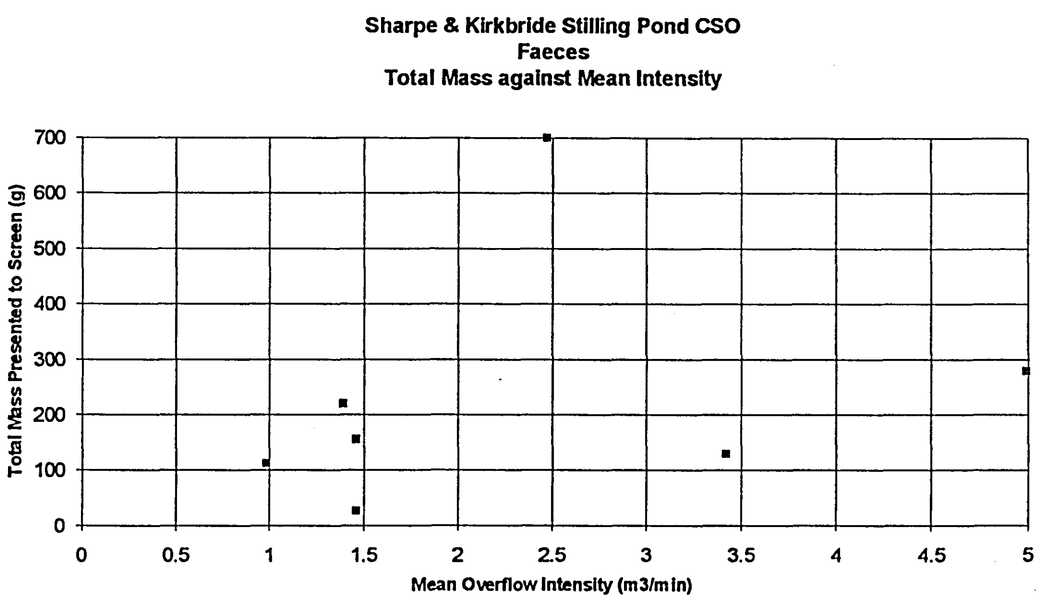


Figure 3.141

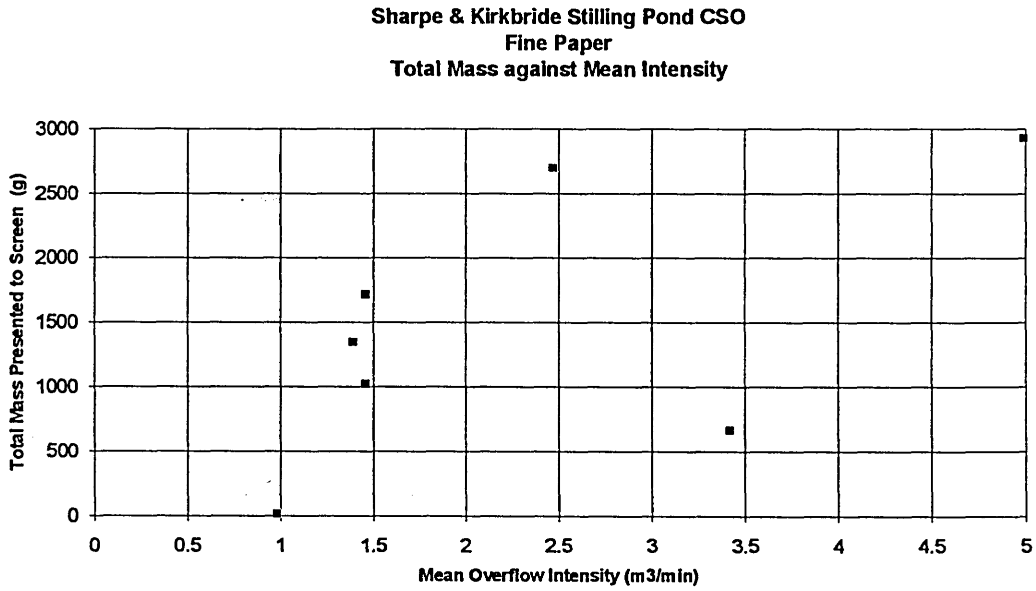


Figure 3.142

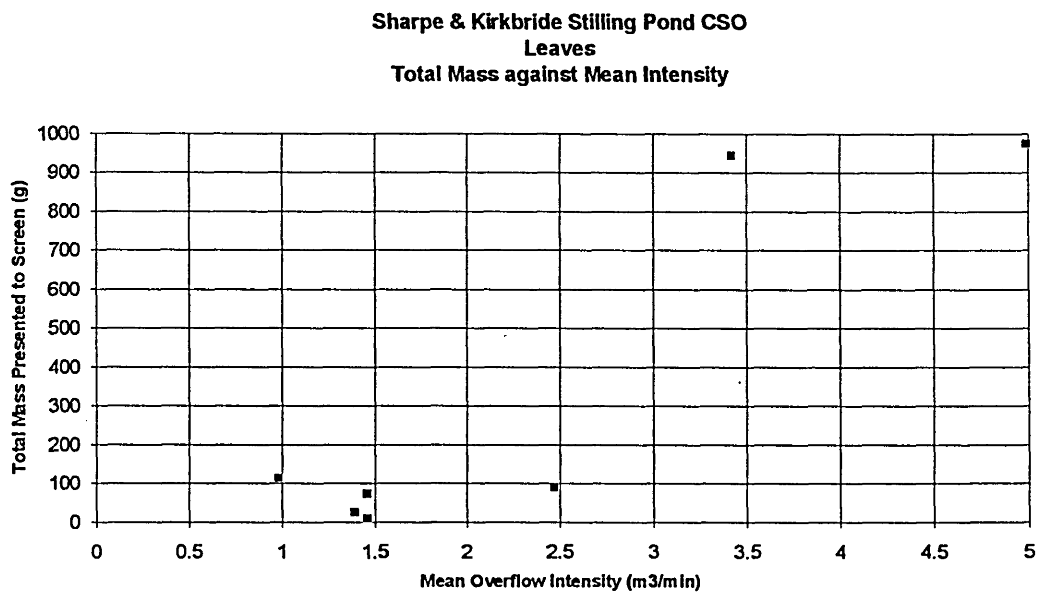


Figure 3.143

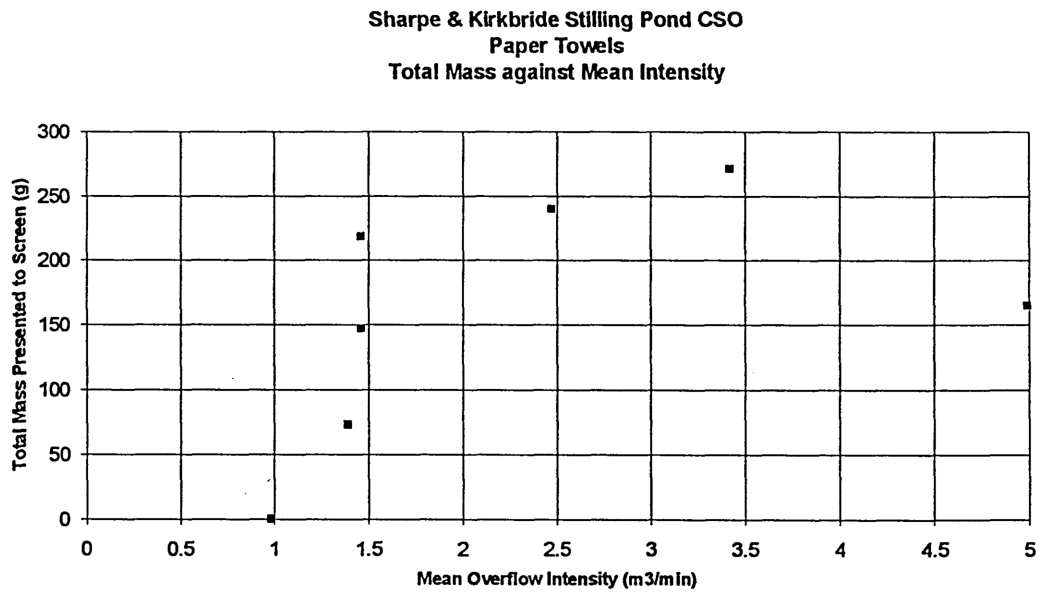


Figure 3.144

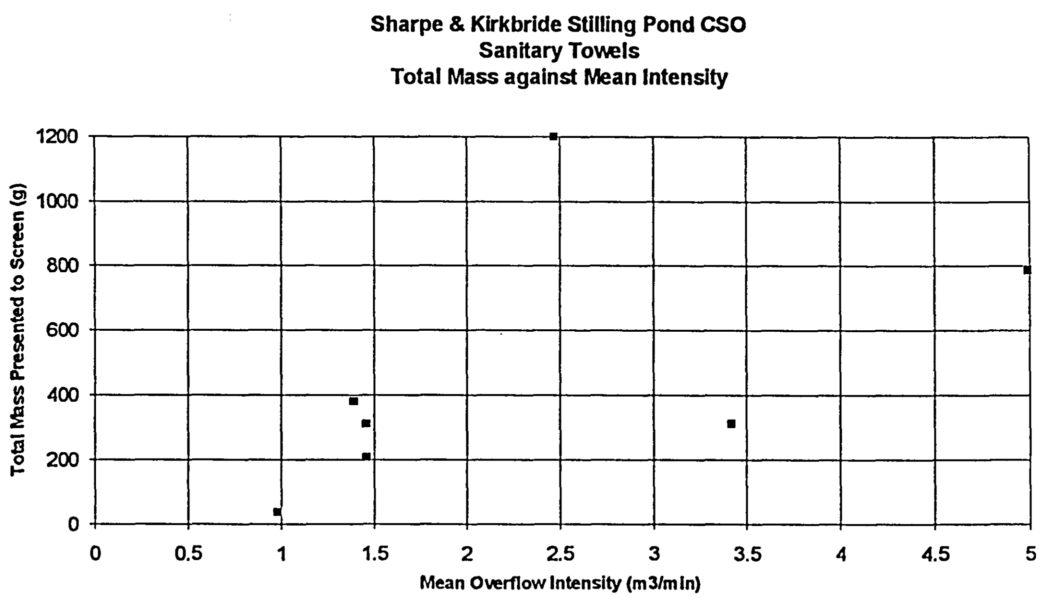


Figure 3.145

Extended Stilling pond CSO

Total Mass presented to Screen against Mean Overflow Intensity

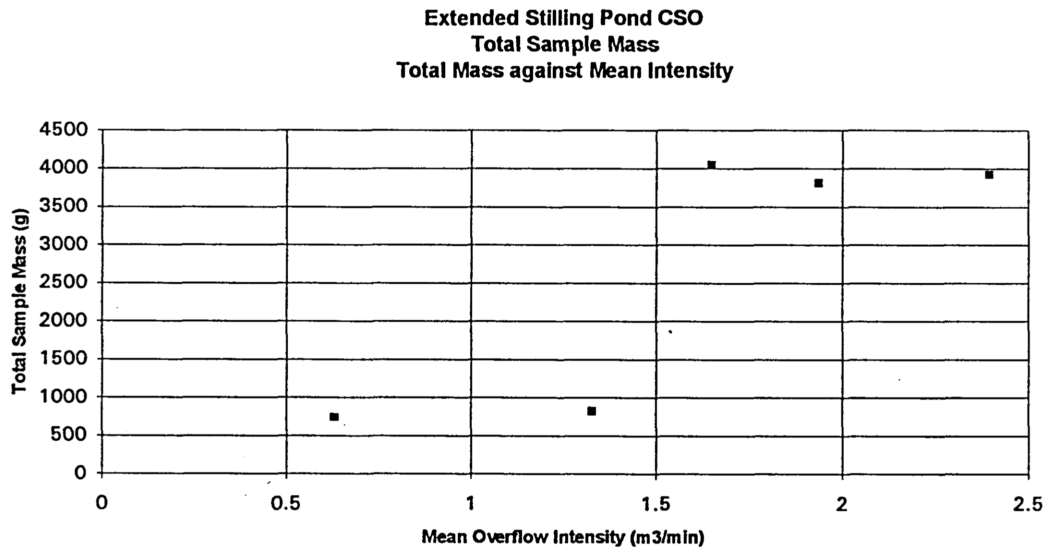


Figure 3.146

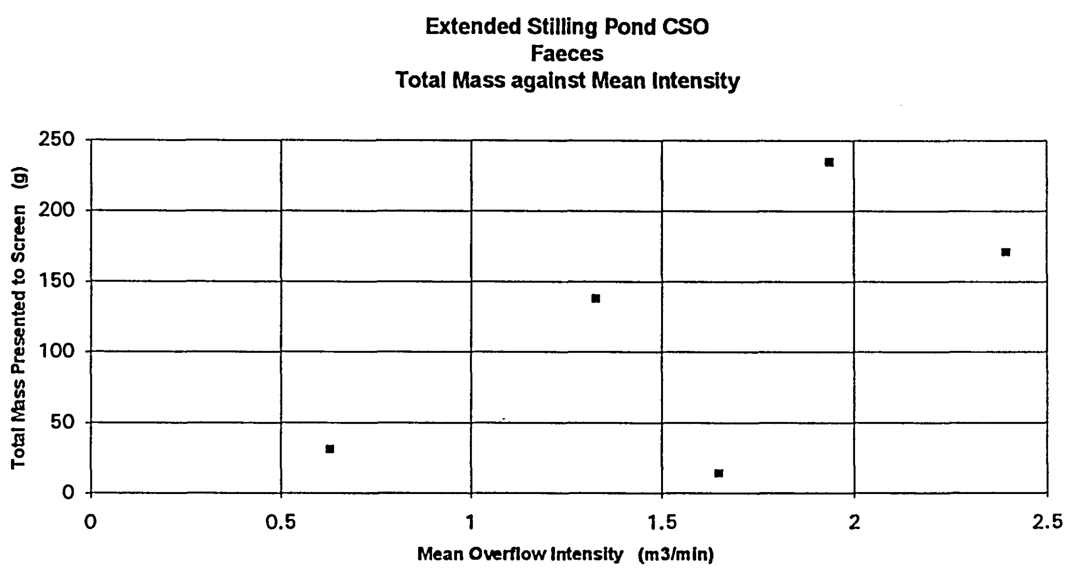


Figure 3.147

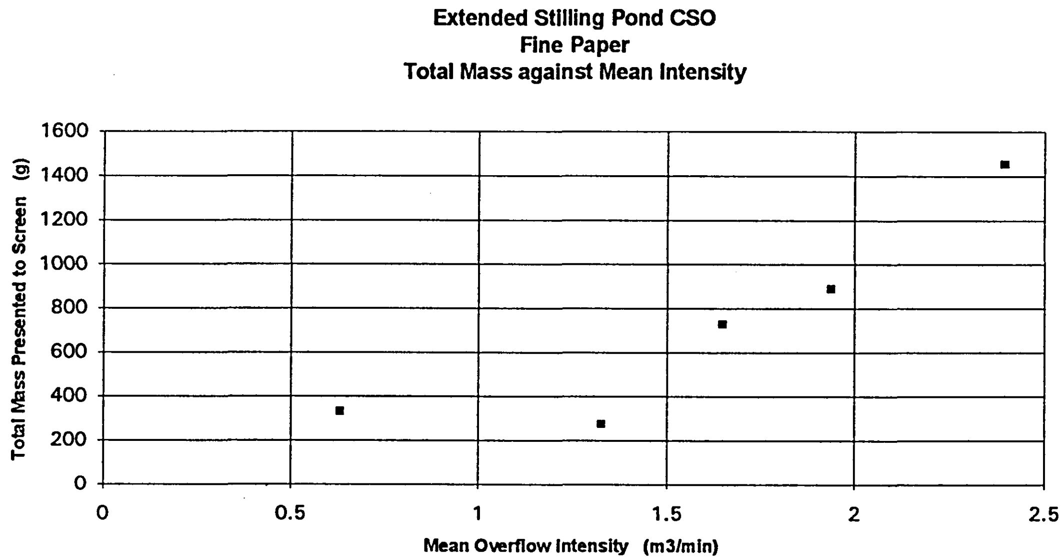


Figure 3.148

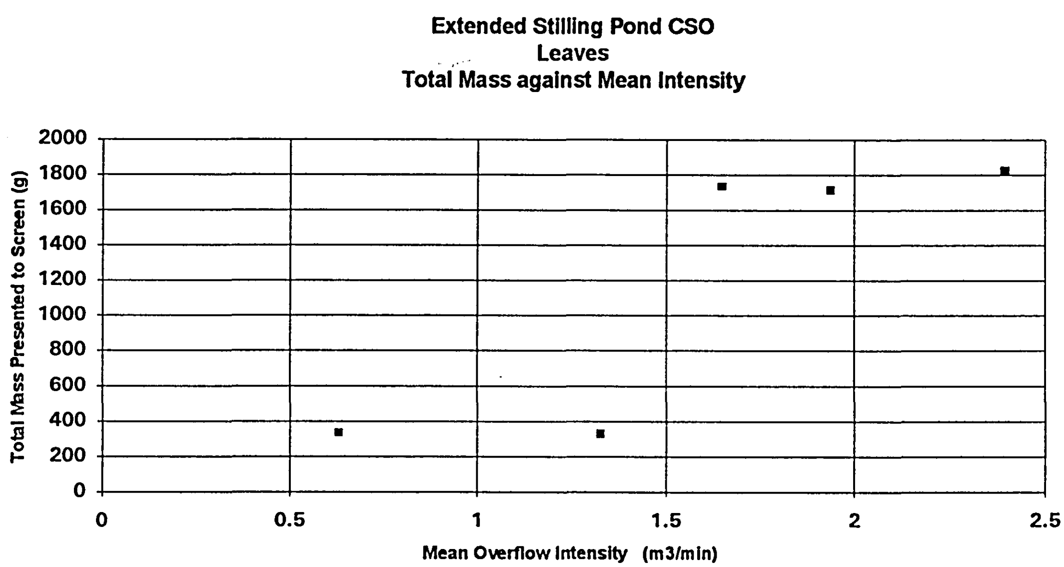


Figure 3.149

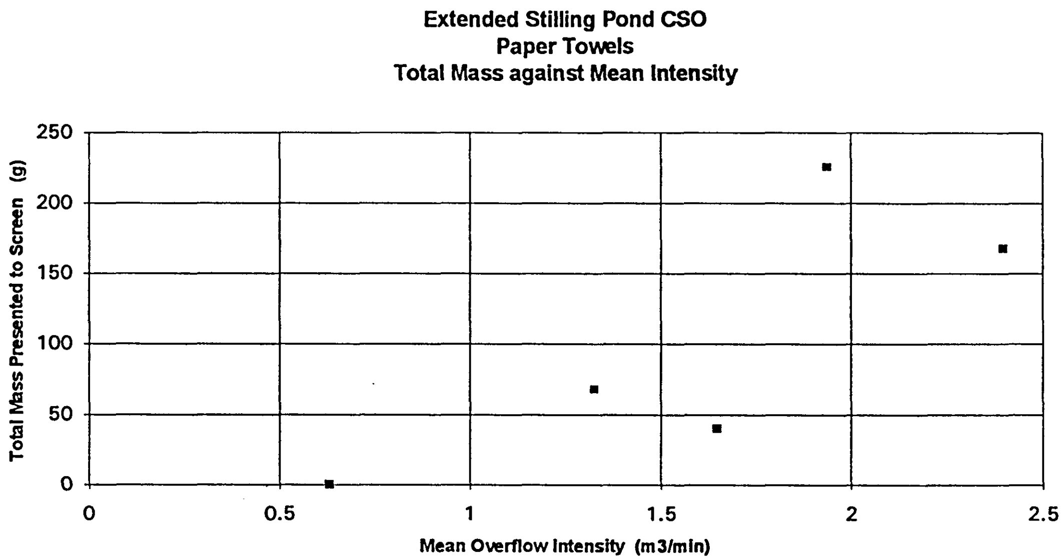


Figure 3.150

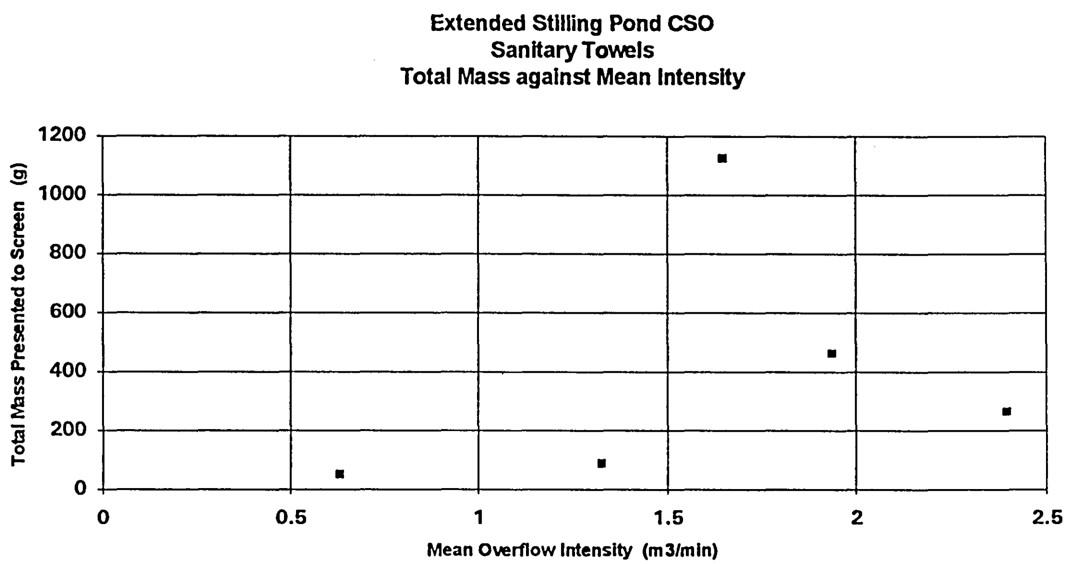


Figure 3.151

BOTH CSO SITES

Total Mass presented to Screen against Mean Overflow Intensity

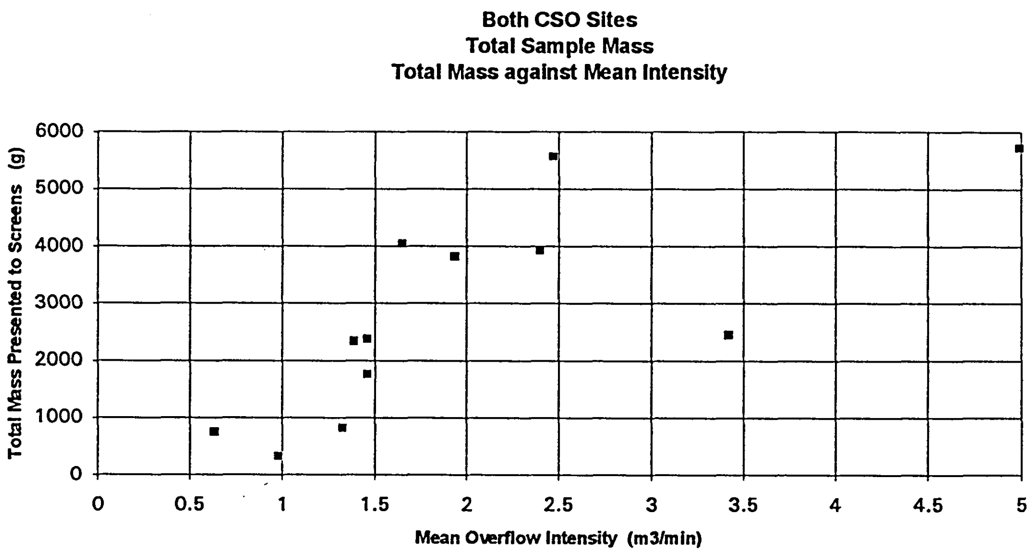


Figure 3.152

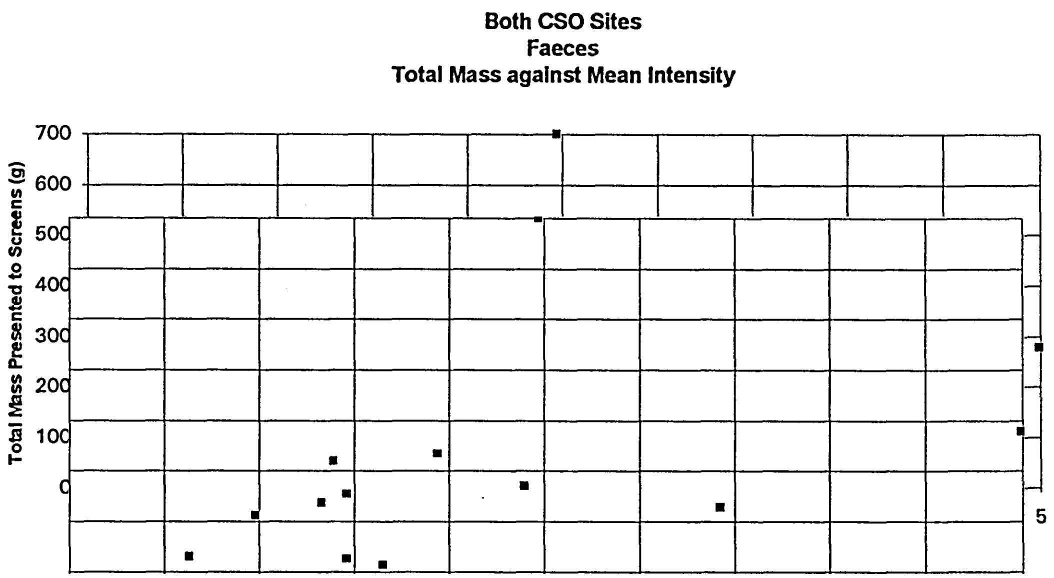


Figure 3.153

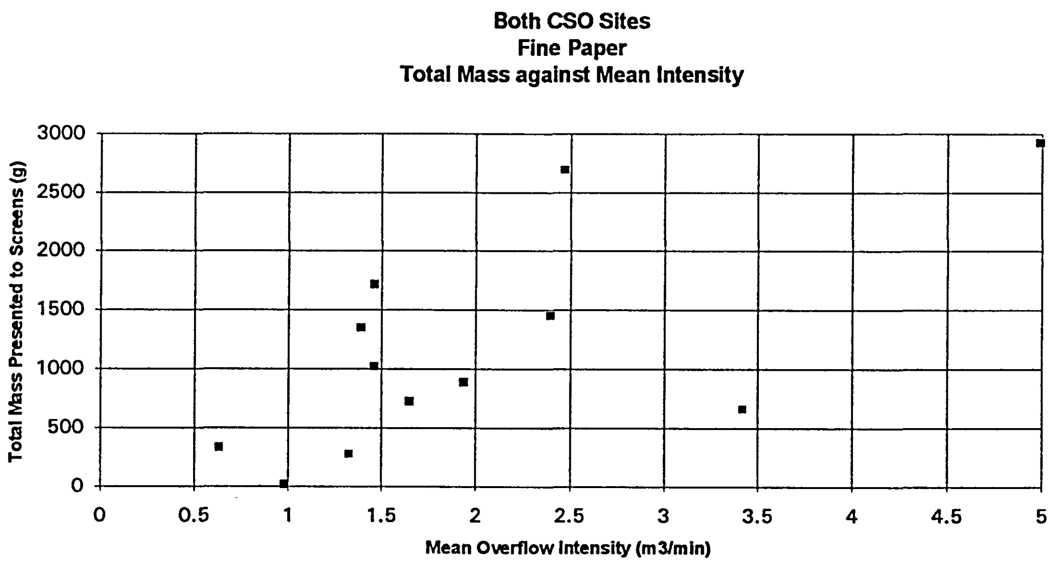


Figure 3.154

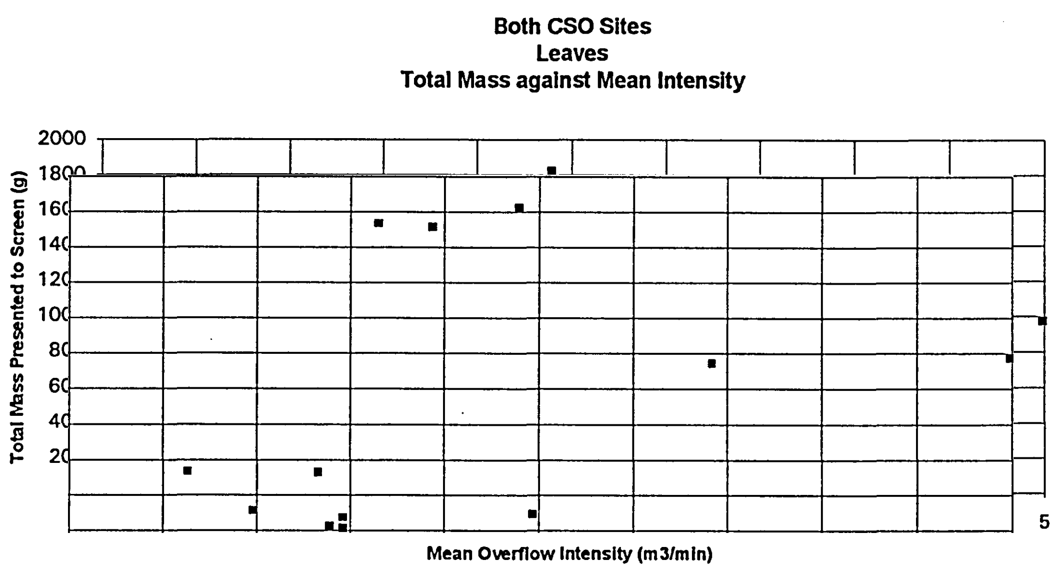


Figure 3.155

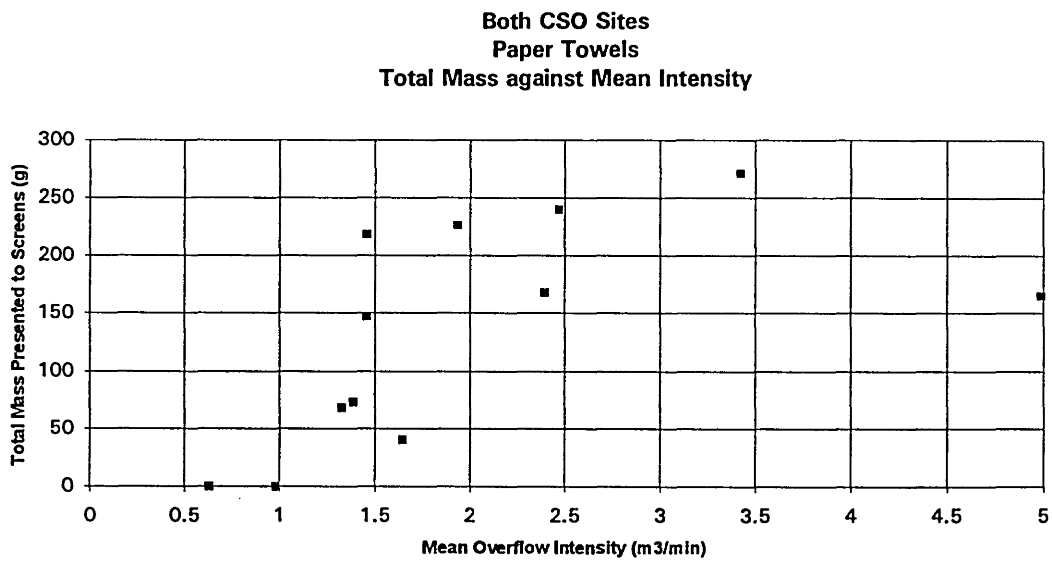


Figure 3.156

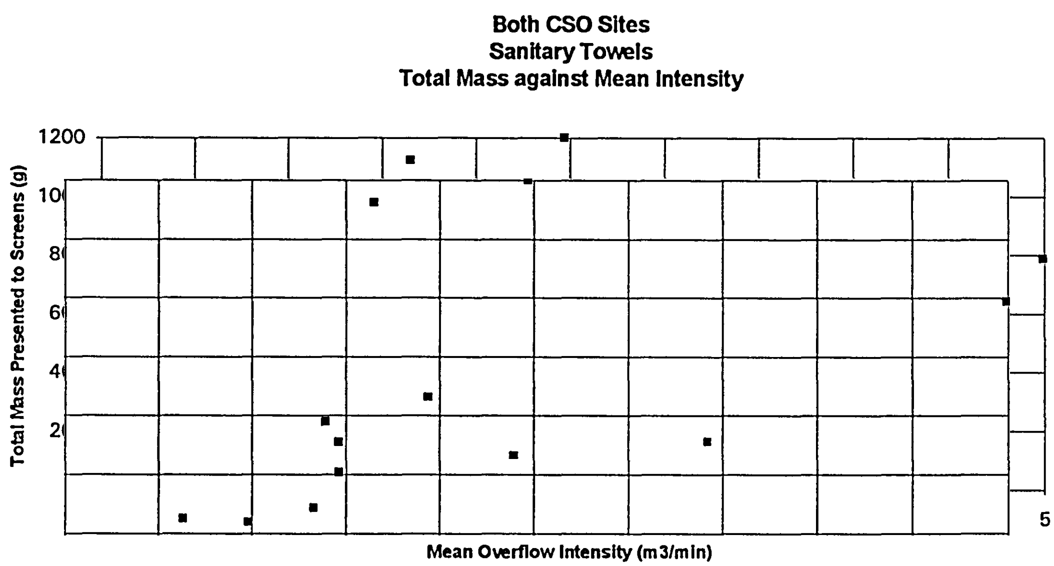


Figure 3.157

Long Lane STW - Inclined Bar Screen

Screen Retention Efficiency against Mean Flowrate

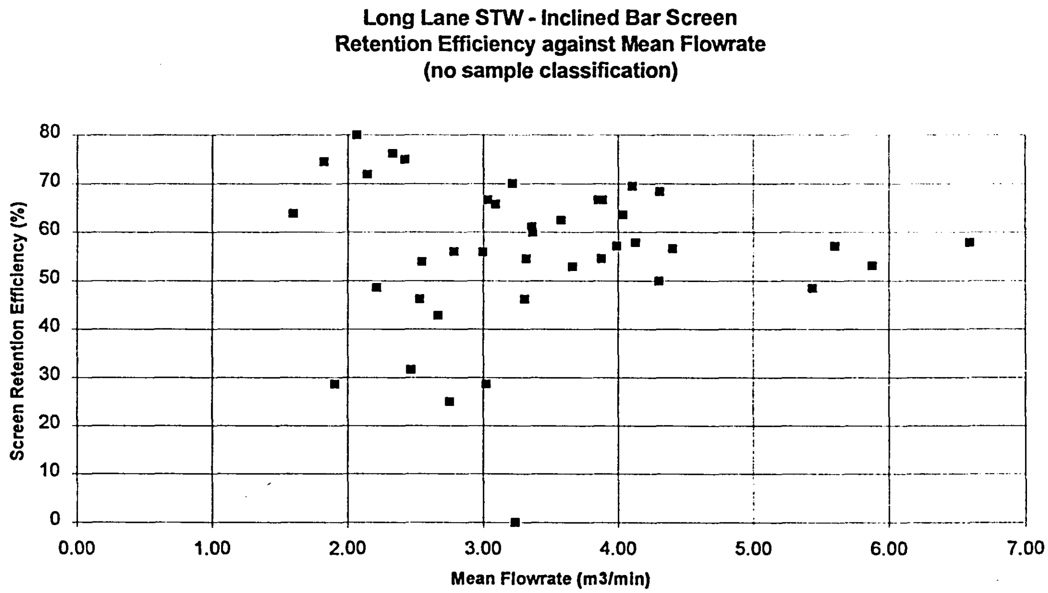


Figure 3.158

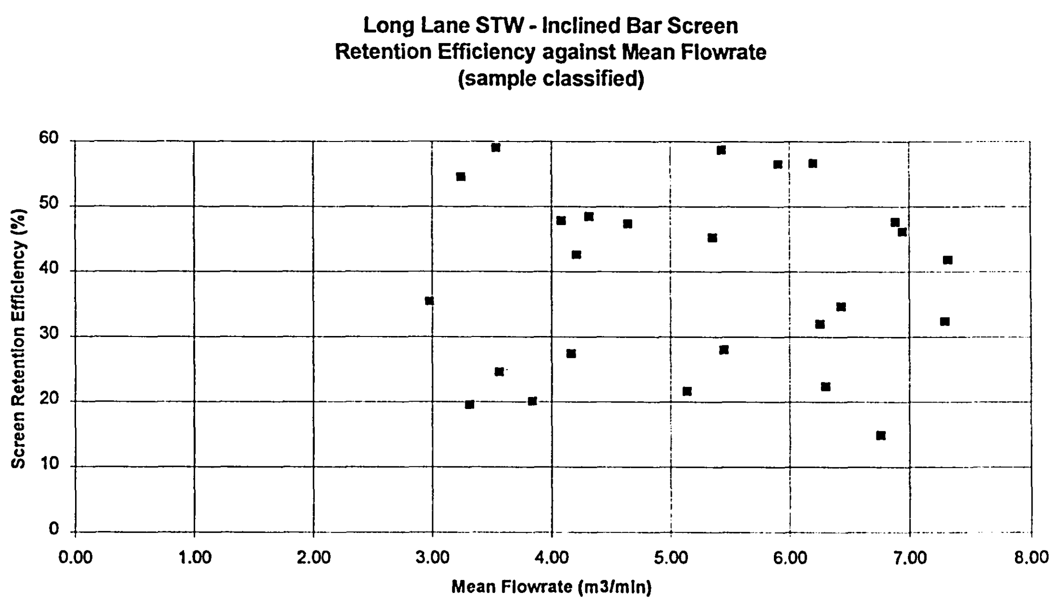


Figure3.159

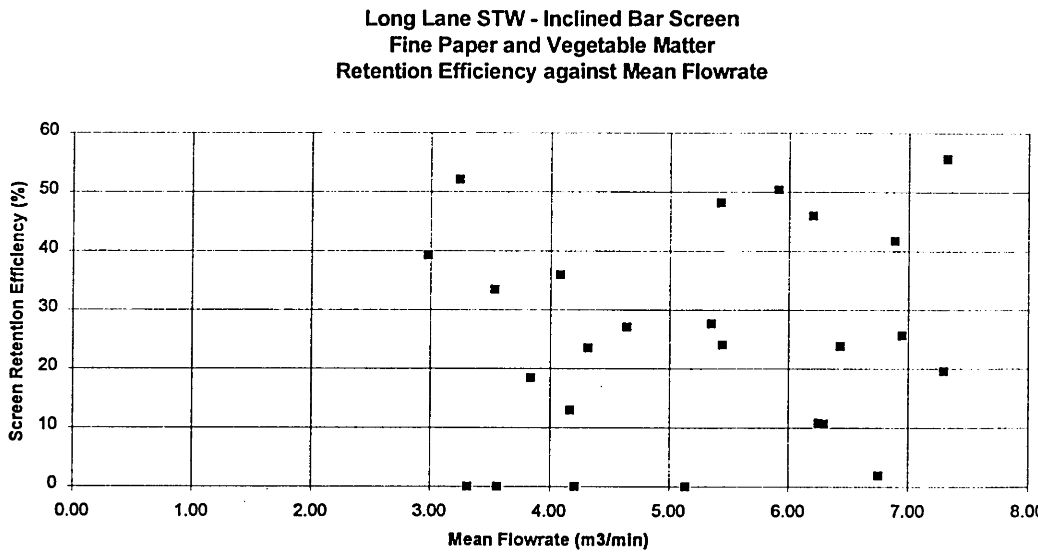


Figure3.160

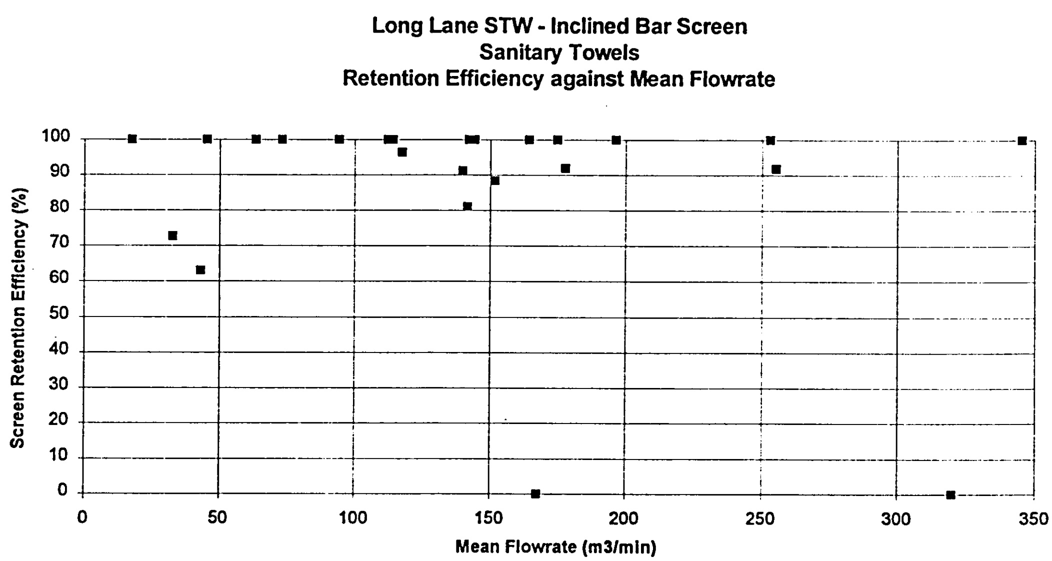


Figure3.161

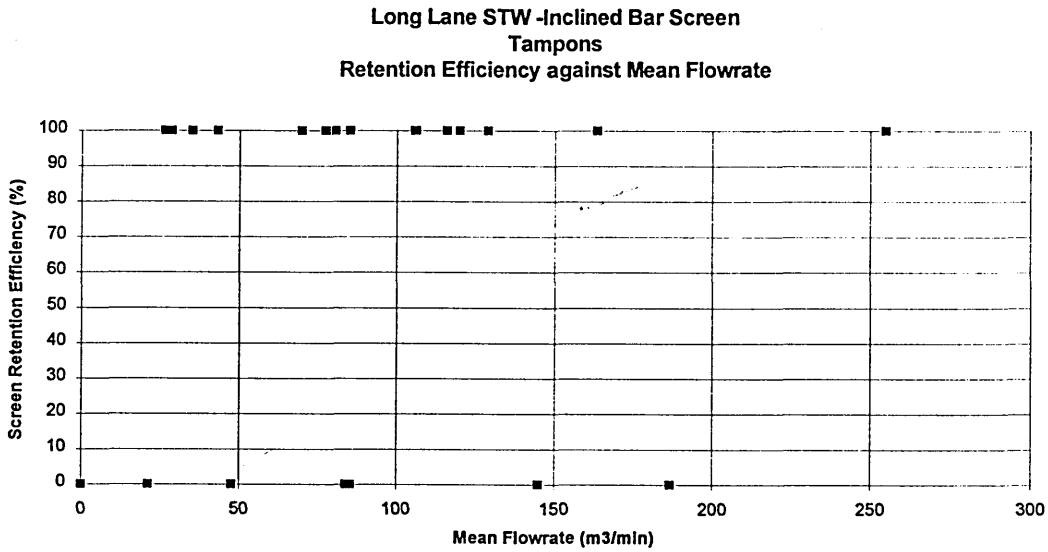

Long Lane STW -Inclined Bar Screen
Tampons
Retention Efficiency against Mean Flowrate
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
50
100
150
200
250
300
Mean Flowrate (m3/min)

Figure3.162

Long Lane STW - D-Screen

Screen Retention Efficiency against Mean Flowrate

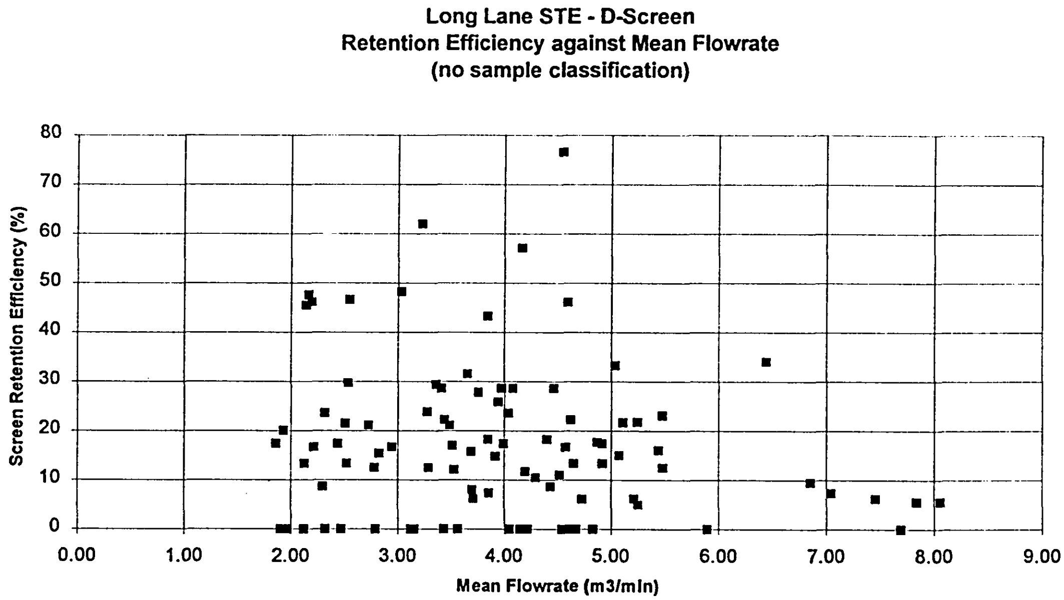


Figure 3.163

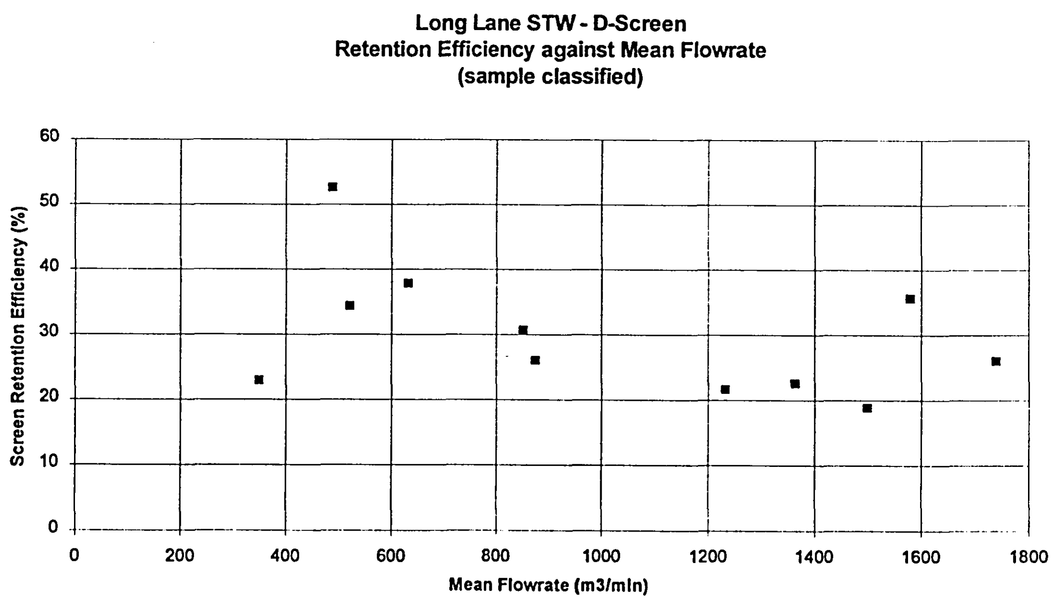


Figure 3.164

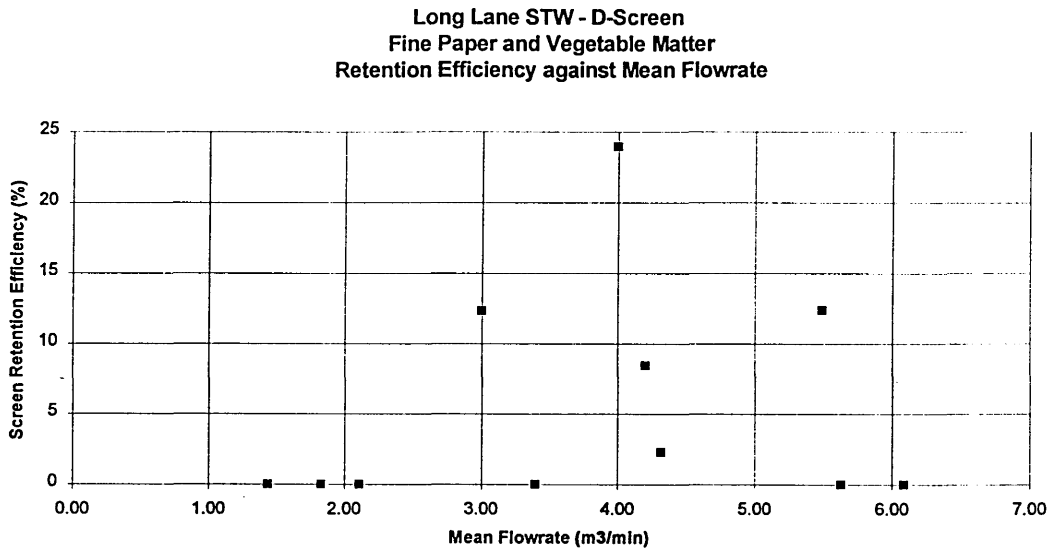


Figure 3.165

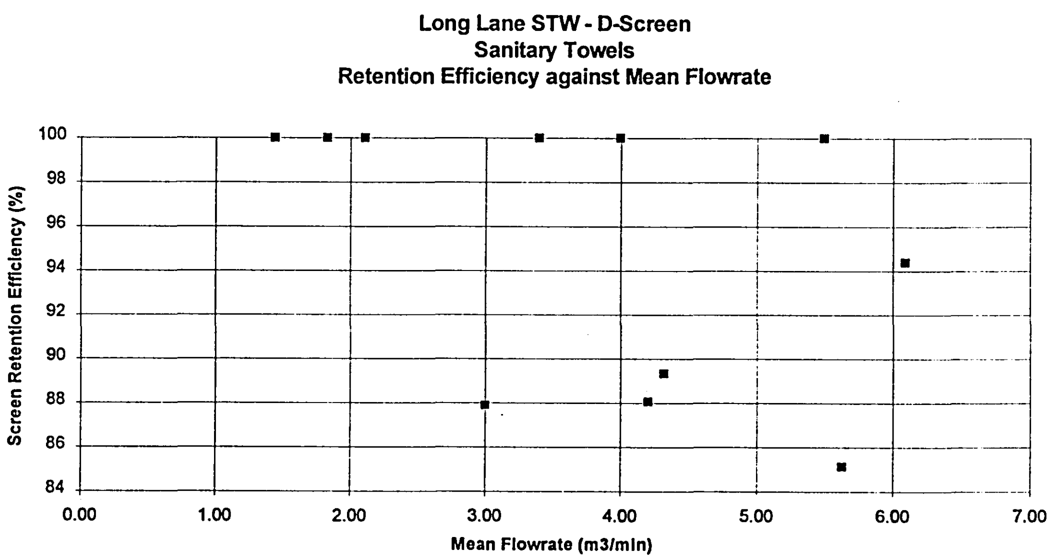


Figure 3.166

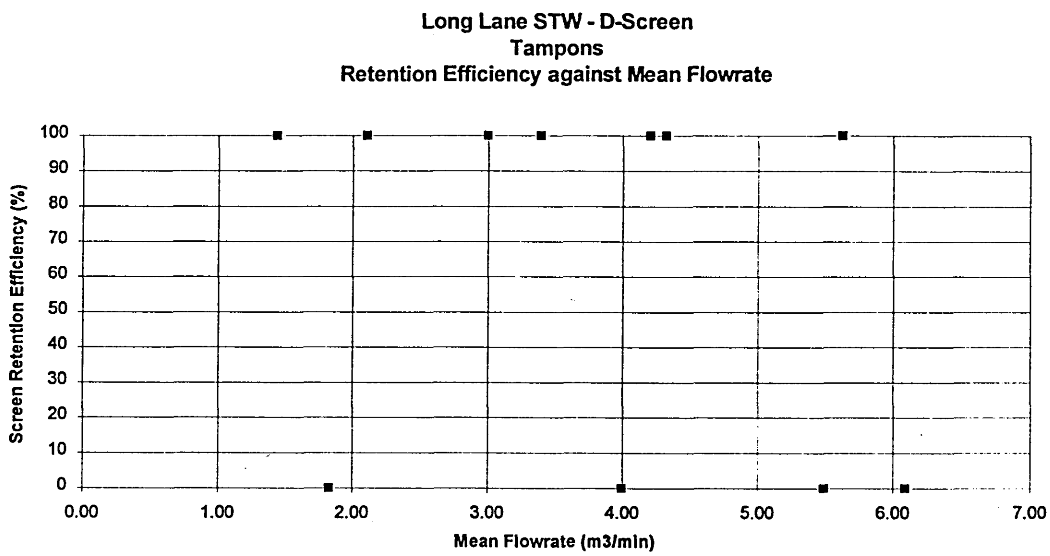

Long Lane STW - D-Screen
Tampons
Retention Efficiency against Mean Flowrate
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Mean Flowrate (m3/min)

Figure 3.167

Long Lane STW - Inclined Bar Screen

Screen Retention Efficiency against Total Mass presented to Screen

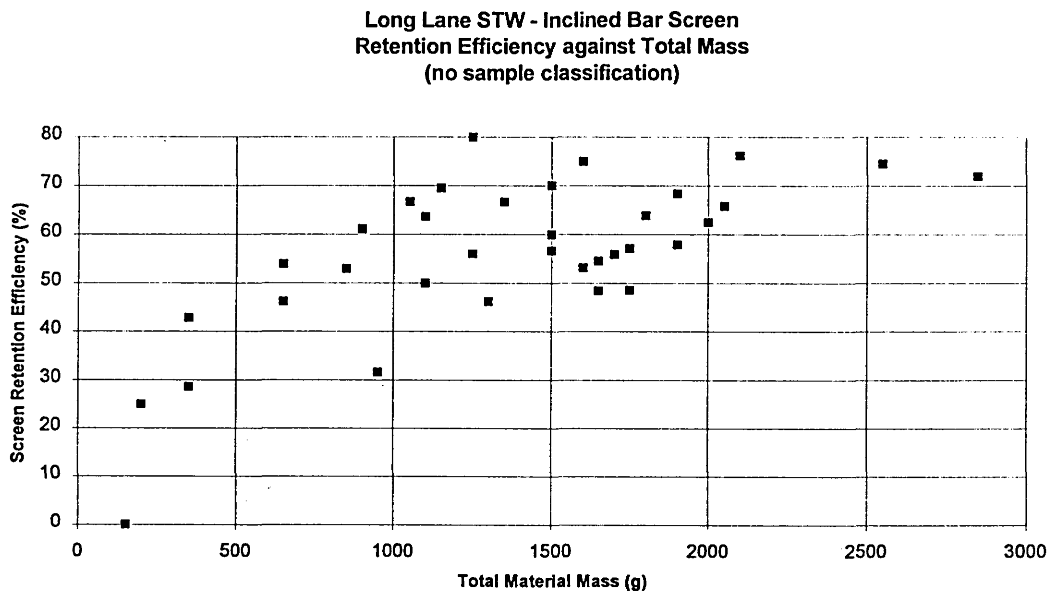


Figure 3.168

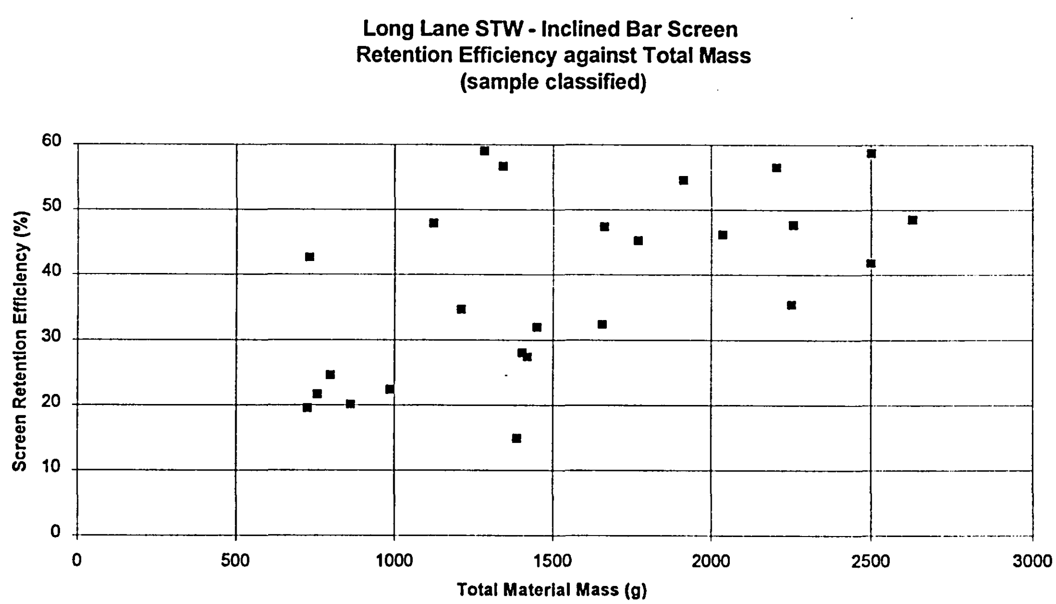


Figure 3.169

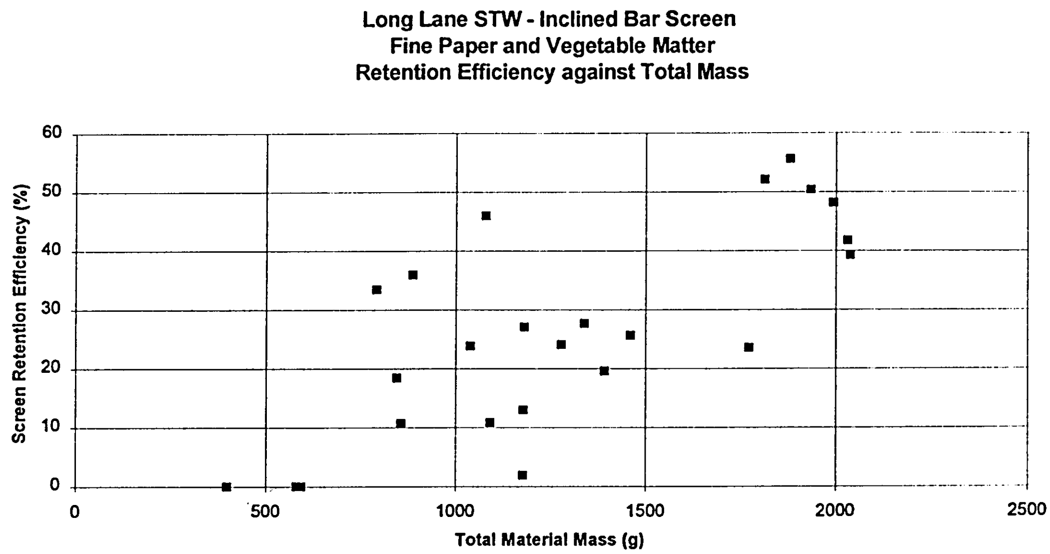


Figure 3.170

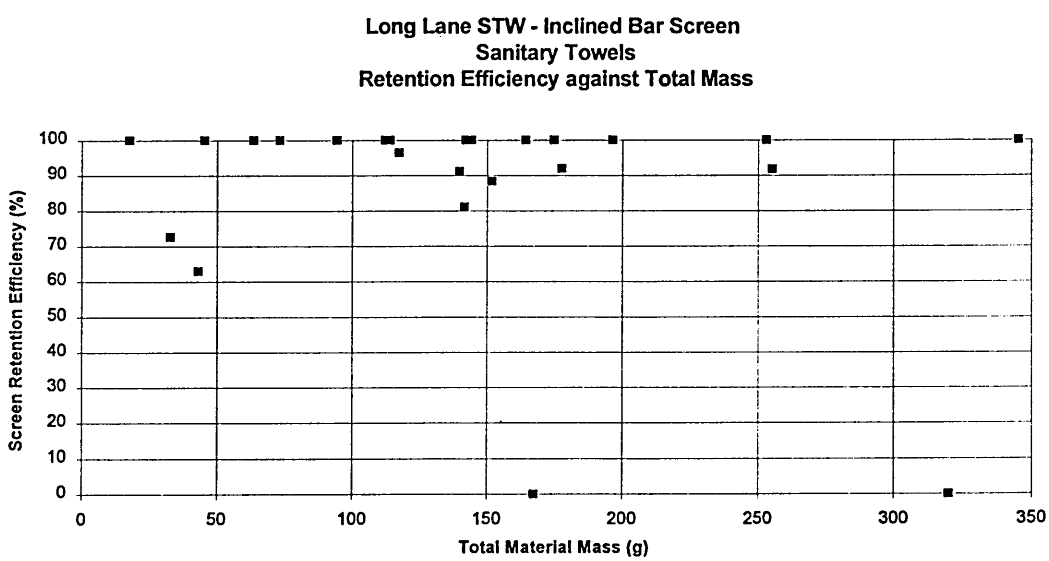


Figure 3.171

Long Lane STW - Inclined Bar Screen
Tampons
Retention Efficiency against Total Mass

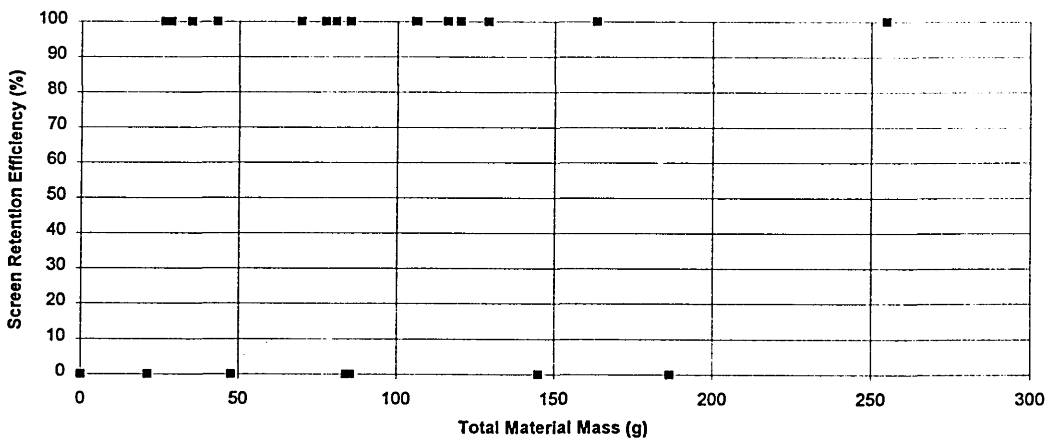


Figure 3.172

Long Lane STW - D-Screen

Screen Retention Efficiency against Total Mass presented to Screen

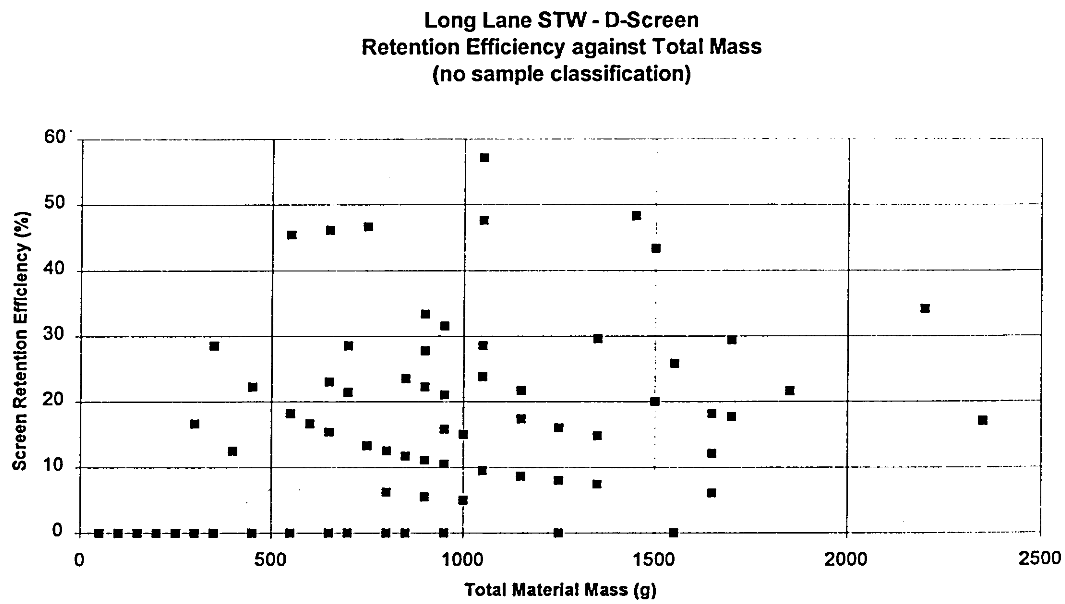


Figure 3.173

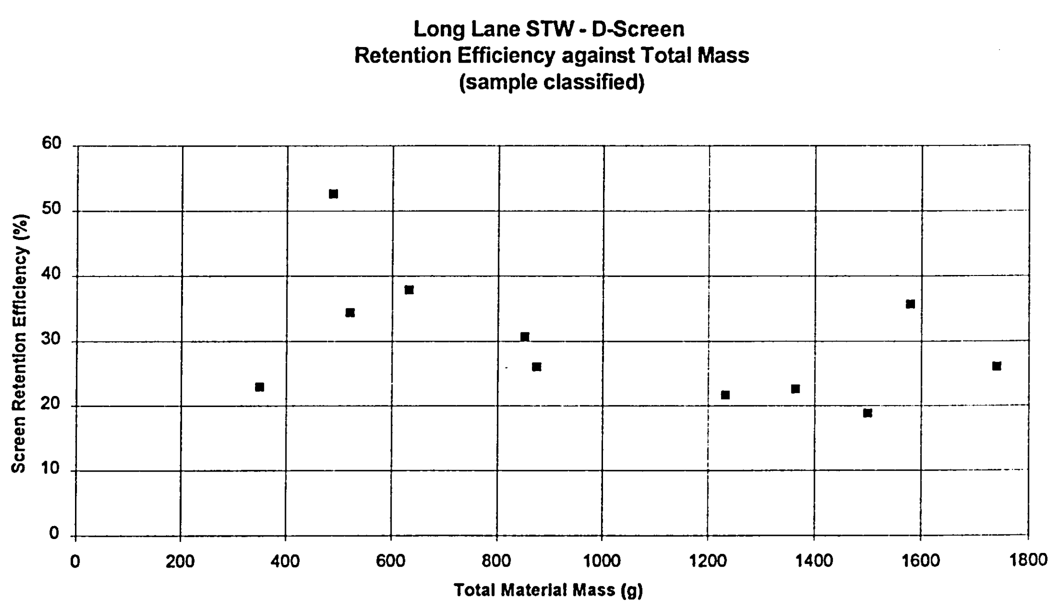


Figure 3.174

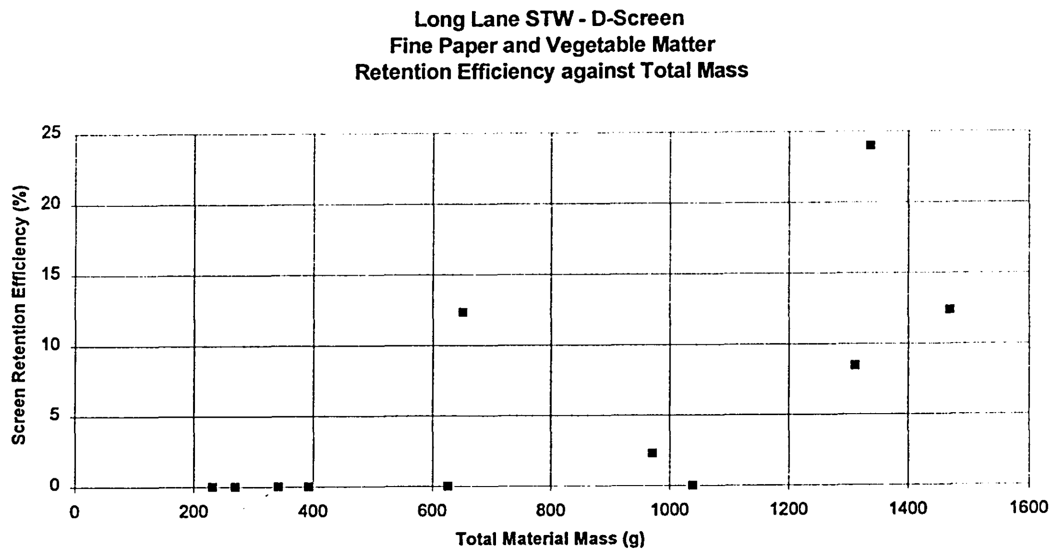


Figure 3.175

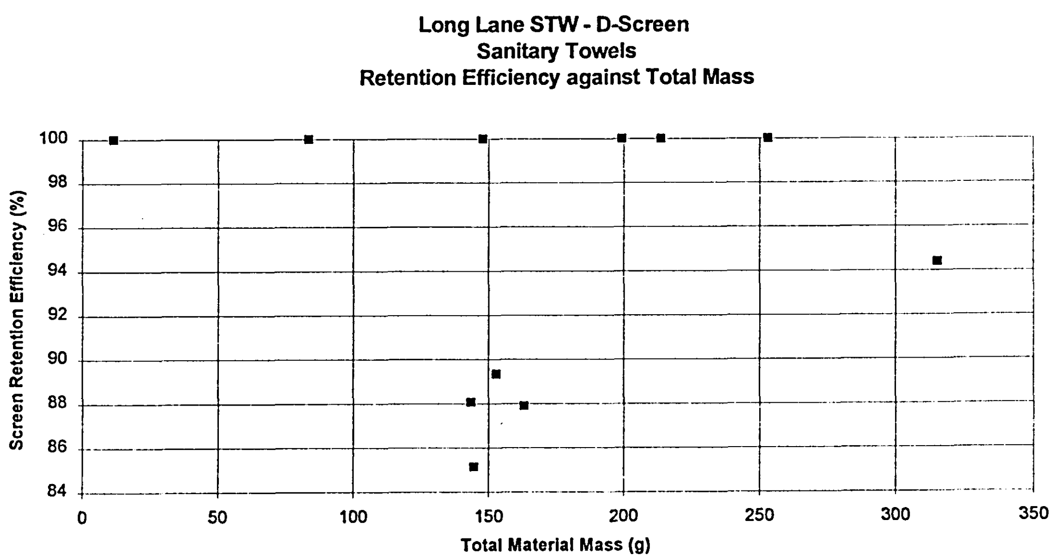


Figure 3.176

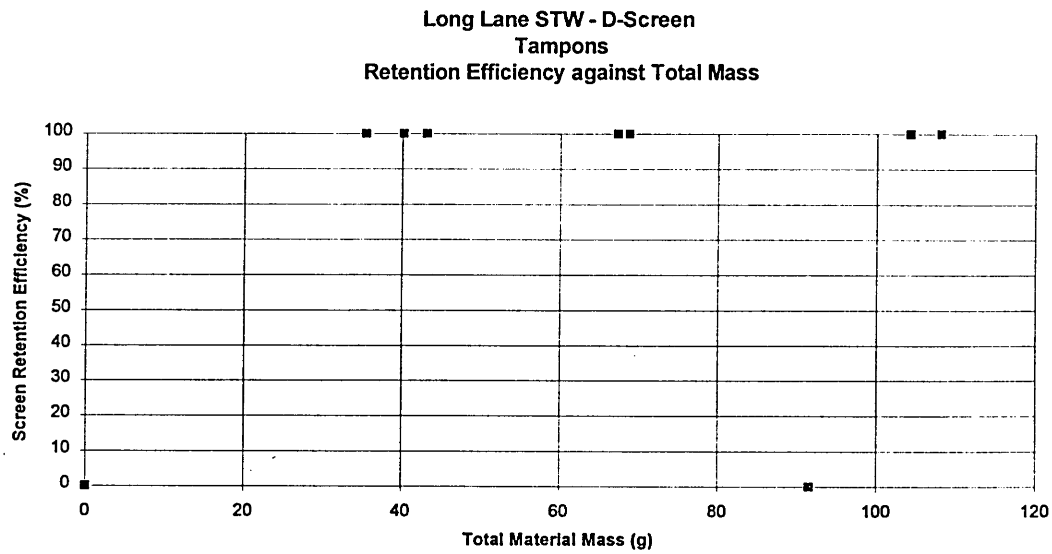

Long Lane STW - D-Screen
Tampons
Retention Efficiency against Total Mass
Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Total Material Mass (g)

Figure 3.177

Long Lane Sewage Treatment Works Inclined Bar Screen

Total Mass presented to Screen against Mean Flowrate

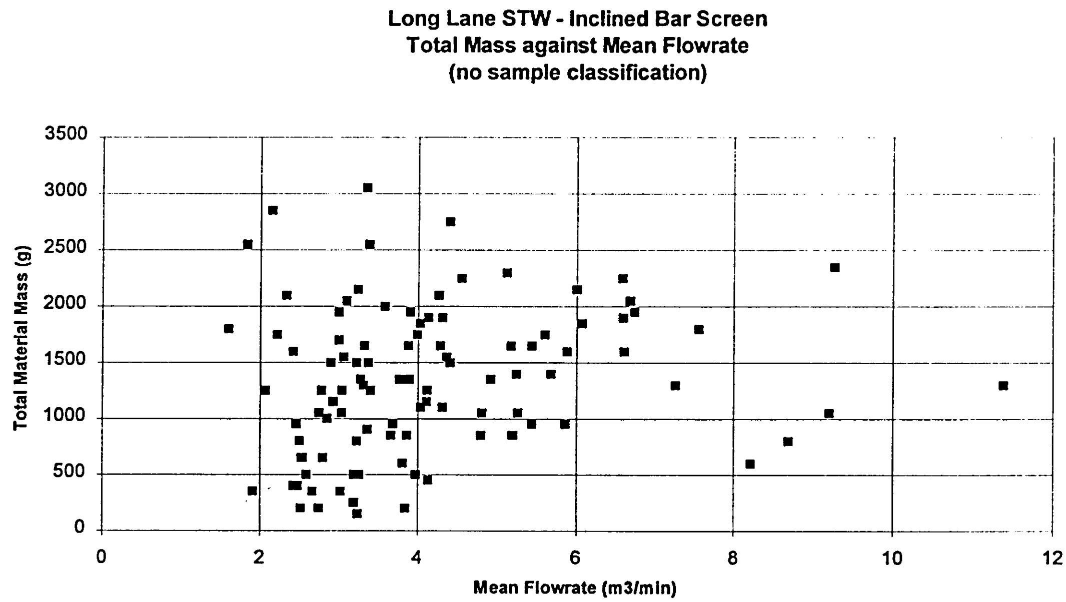


Figure 3.178

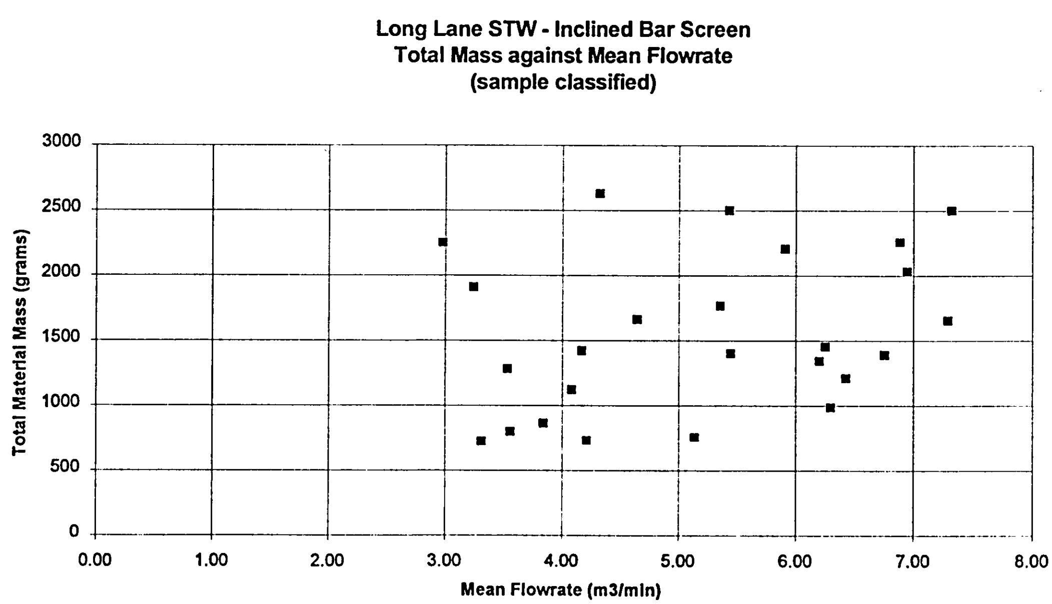


Figure 3.179

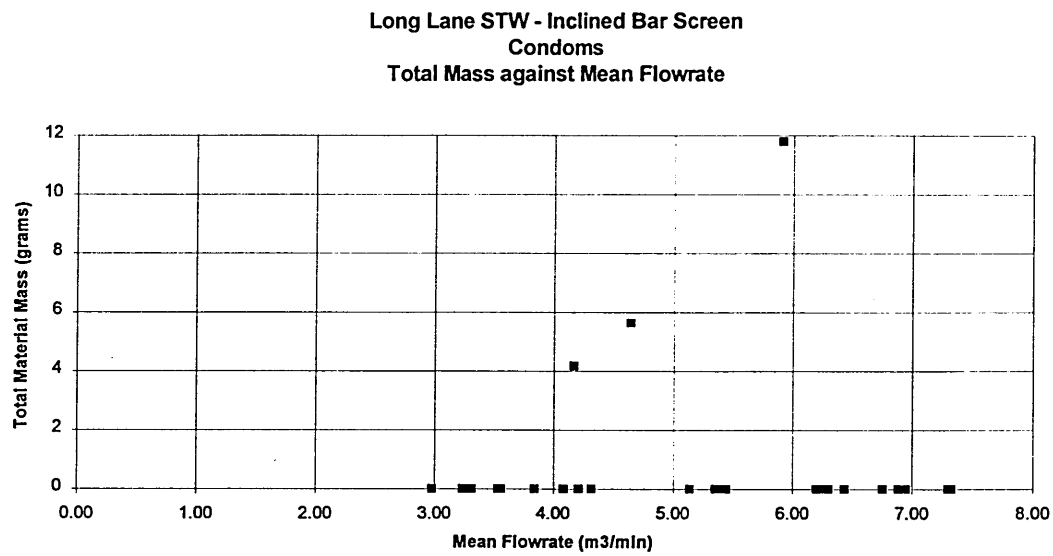


Figure3.180

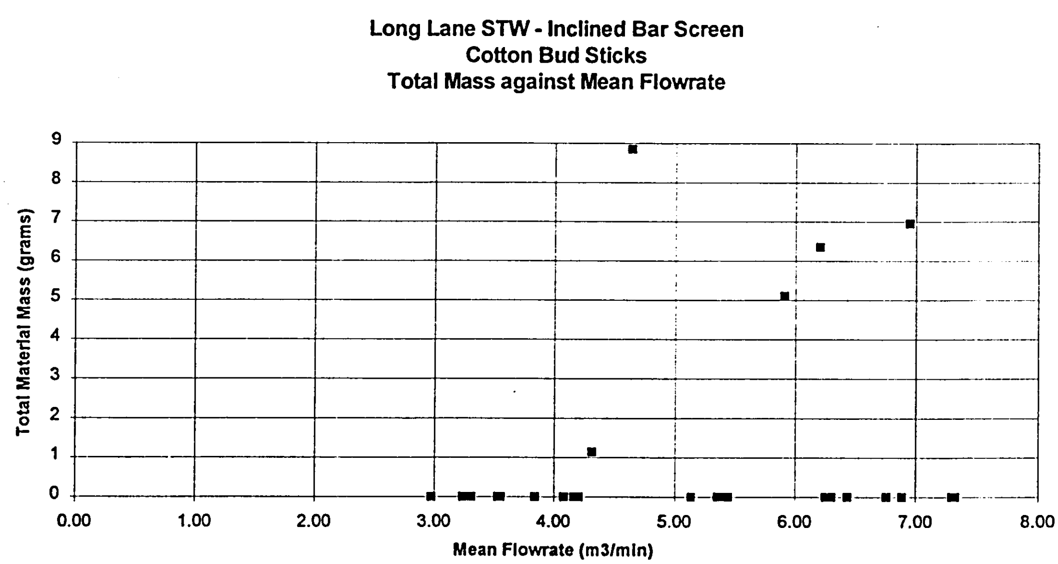


Figure3.181

Long Lane STW - Inclined Bar Screen
Faeces and Vegetable Matter
Total Mass against Mean Flowrate

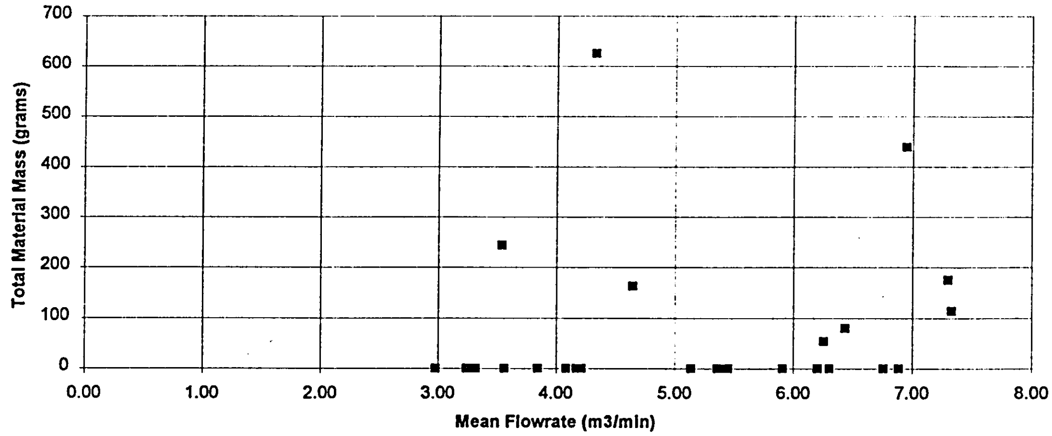


Figure 3.182

Long Lane STW - Inclined Bar Screen
Fine Paper and Vegetable Matter
Total Mass against Mean Flowrate

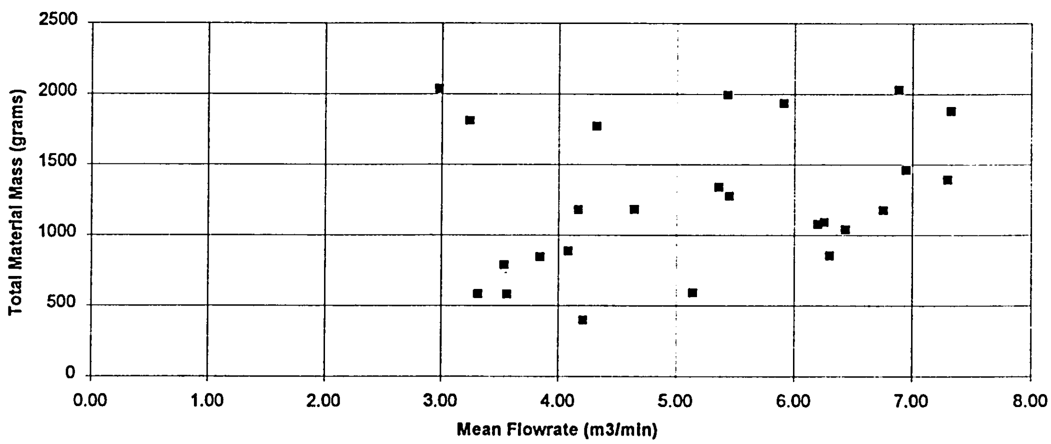


Figure3.183

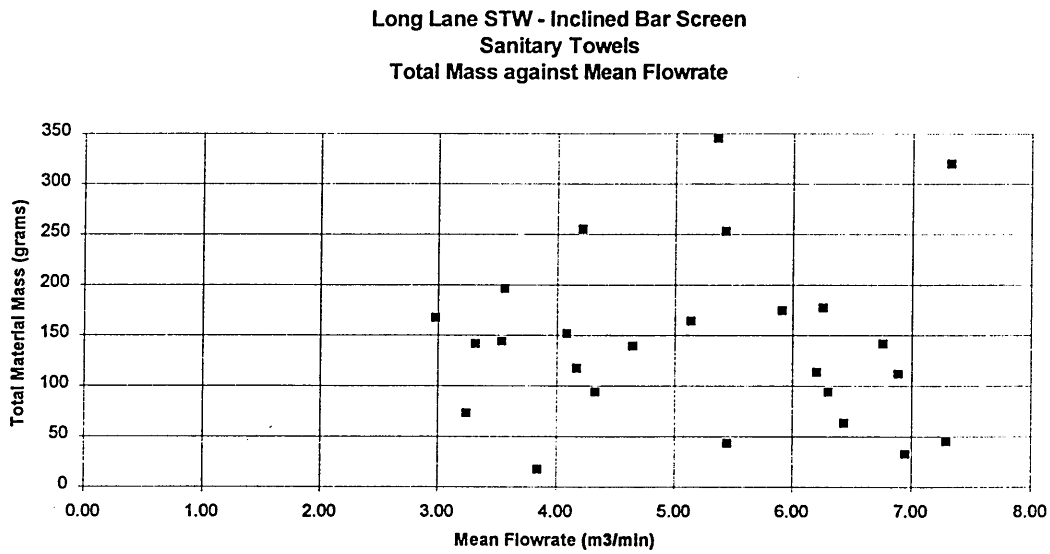


Figure3.184

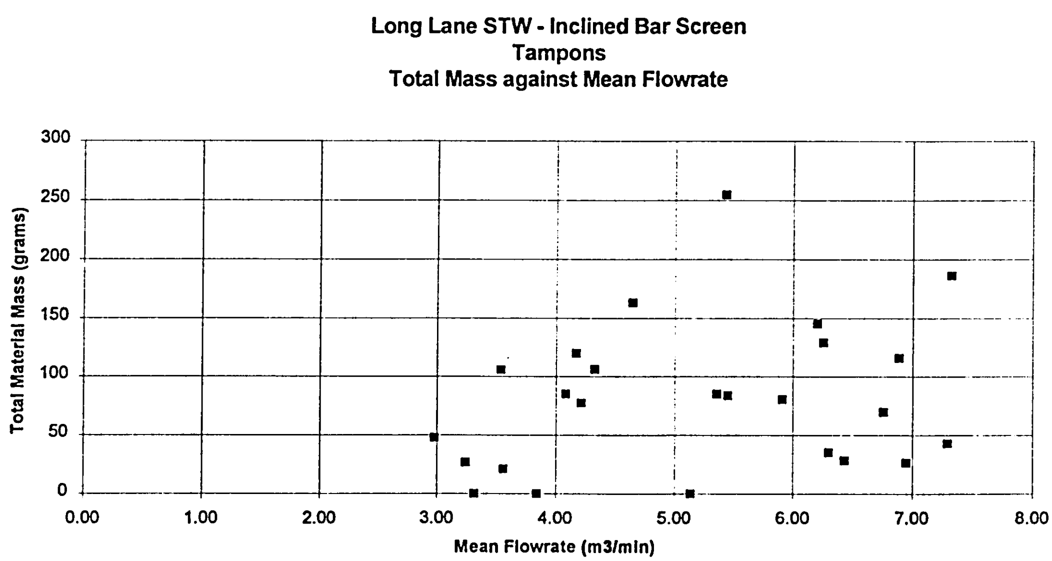


Figure 3.185

Long Lane Sewage Treatment Works D-Screen

Total Mass presented to Screen against Mean Flowrate

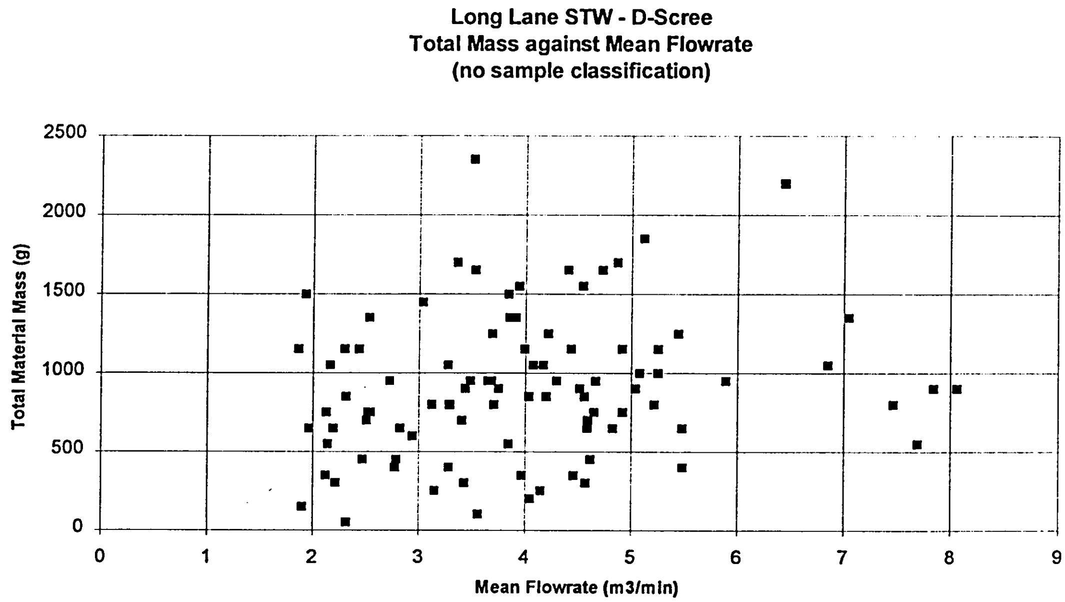


Figure 3.186

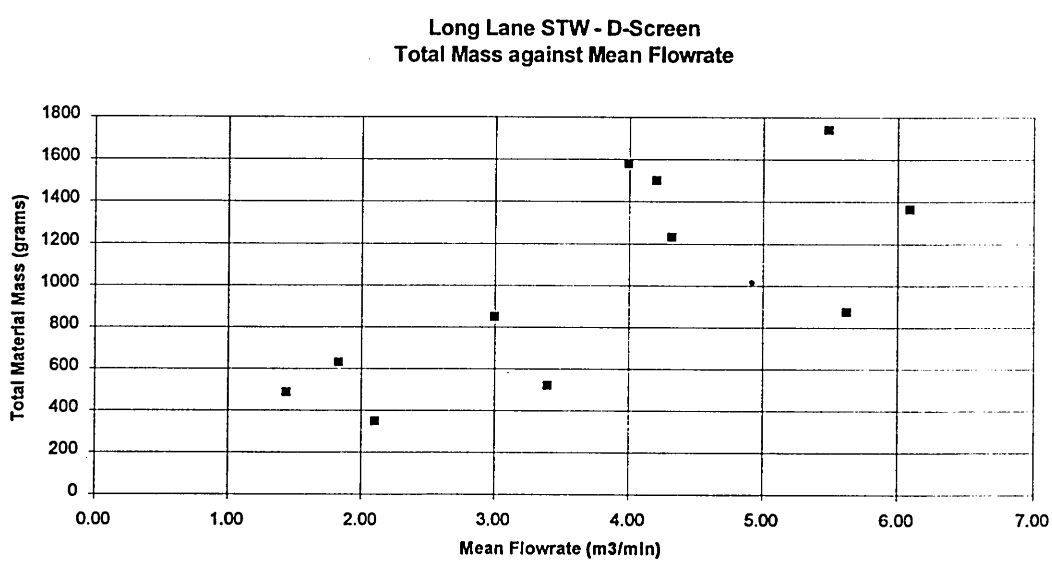


Figure 3.187

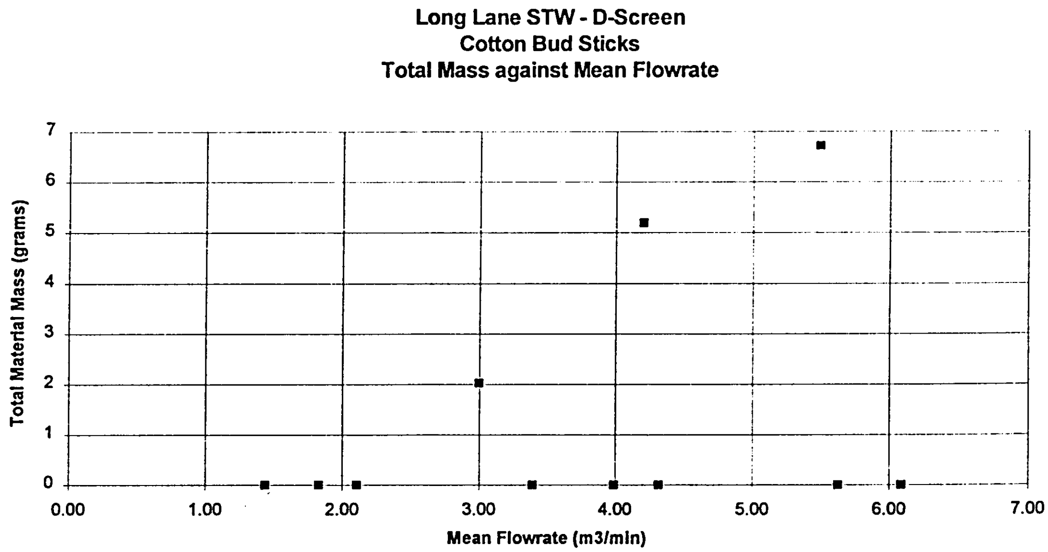


Figure 3.188

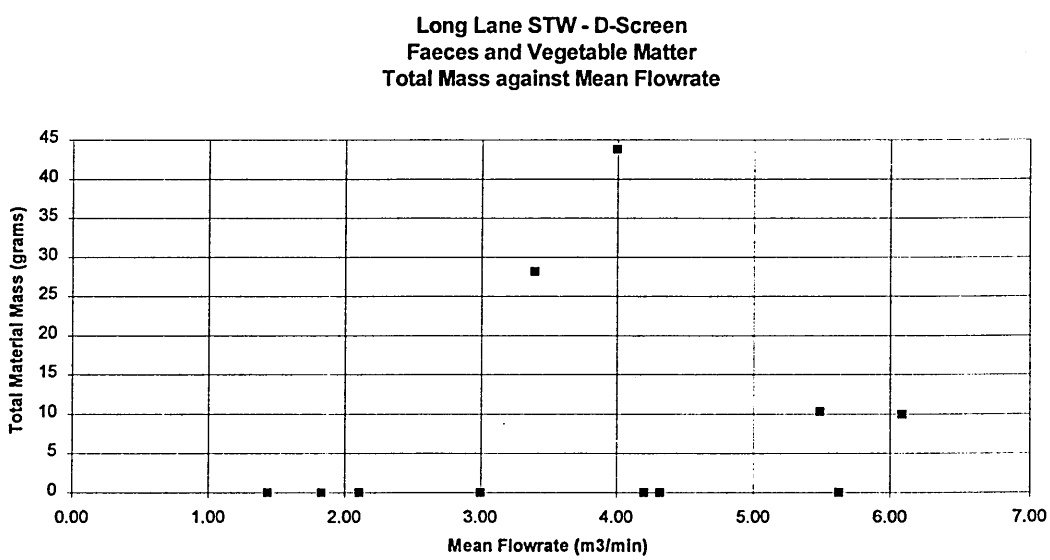


Figure 3.189

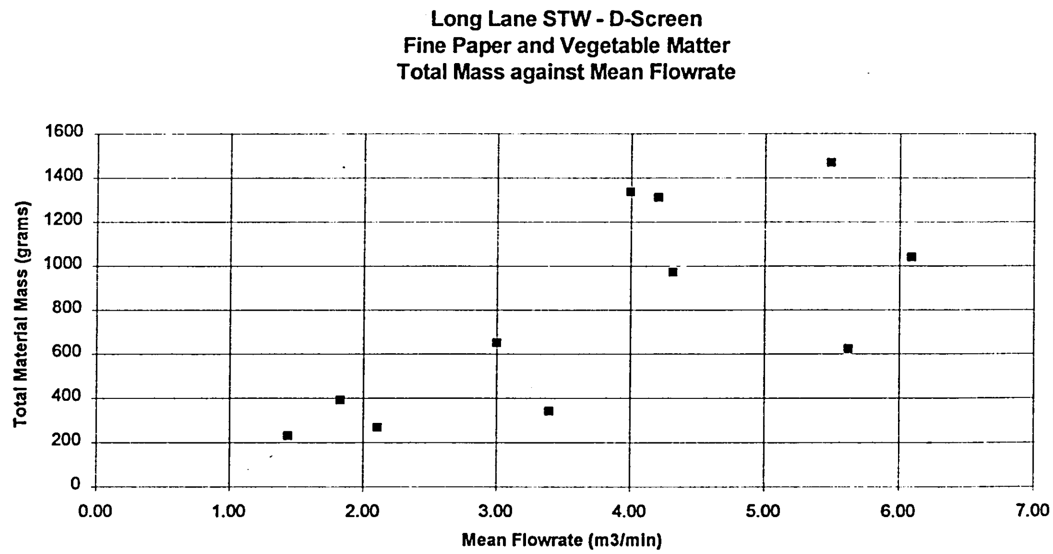


Figure 3.190

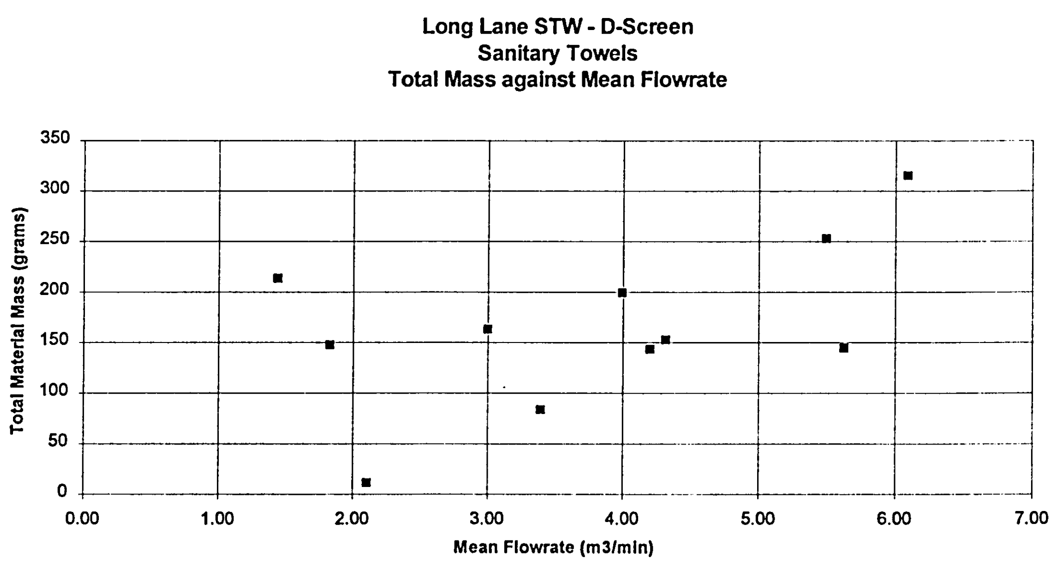


Figure 3.191

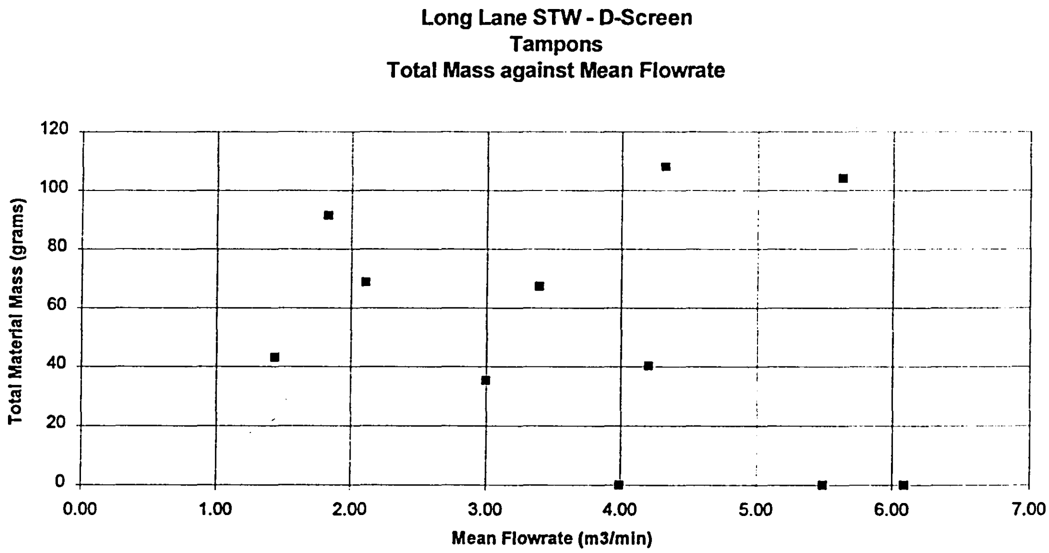

Long Lane STW - D-Screen
Tampons
Total Mass against Mean Flowrate
Total Material Mass (grams)
0
20
40
60
80
100
120
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
Mean Flowrate (m3/min)

Figure 3.192

3.9 Discussion

3.9.1 Combined sewer overflows

The main materials presented to the screens at the combined sewer overflow sites were:

Faeces

Fine Paper (Toilet Paper)

Leaves

Plastic Shells of Sanitary Towels

Sweet Wrappers

Tampons

Thick Paper Towels

Whole Sanitary Towels

Other materials were also presented to the screens but these were either unique to a particular storm event or accounted for less than one percent, of the overall sample collected. Because public complaints regarding aesthetic pollutants contain sightings of sewage (Burchmore and Green, 1993) but particularly sanitary towels, condoms and cotton bud sticks, these materials have been specifically mentioned even when none of the material was detected.

The materials collected at the two CSO sites either show a gradual increase in gross solids mass as the mean overflow intensity increases or a sudden sharp step once a particular overflow intensity has been reached. This was also found to be true with increasing maximum flowrate. This indicates that certain material have a threshold velocity of flow for transportation whereas others are transported continually regardless of the flow conditions. Previous sedimentation studies have shown that certain materials are only transported within the sewerage system once the velocity of flow reaches a certain level. MOSQUITO (Hydraulics Research, 1989) uses a threshold flowrate when modelling material transportation within a sewerage system. When the total gross solids mass from both sites was plotted onto the same graph as the mean overflow intensity, figure 3.152, there appeared to be a trend between the two parameters. However, the relationship between the two sets of data was not clear and further work was carried out to establish this relationship. This analysis is discussed further in chapter 6. A similar plot was produced using the data from both sites for the total mass of gross solids and the maximum flowrate, figure 3.134, a trend seemed to exist between the two parameters but the data points appeared to fall within a fairly broad band. The scatter of points on the combined graphs of screen retention efficiency against total gross solids mass, mean overflow intensity and maximum flowrate, figures 3.101, 3.116 and 3.86, make it difficult to ascertain if any relationship exists between the parameters. However, there seems to be a rising trend with screen retention efficiency and total gross solids mass and screen retention efficiency and maximum flowrate. A falling trend appears to exist between screen retention efficiency and mean overflow intensity.

Faeces : The percentages of the overall sample mass for this material are not representative of the total amount of faeces being presented to the screens. The material will be broken down within the sewer system and a proportion of the faeces passing through the screens will also be forced through the Copasacs by the spill flow. Only the hard nodules of faeces will be retained by the screen or trapped by the Copasacs in the spill chamber. However, the faecal material has been included in the analysis because there was evidence of it in every sample and the material which was still intact on the Copasac would normally be passed to the river causing aesthetic pollution. Most of the faeces found at Sharpe and Kirkbride stilling pond CSO and all of the faeces found at Extended stilling pond CSO were retained by the screens although conclusions from this cannot be drawn with the figures being underestimates of the total amount of material. The bar charts of faeces mass against mean overflow intensity and maximum flowrate for both CSO sites, figures 3.34, 3.45, 3.57 and 3.68 tend to indicate that faeces are continually transported within the sewerage system regardless of the velocity of flow. There appeared to be a trend between the total mass of faeces presented to the screen and the mean overflow intensity when the relationship was examined for the Sharpe and Kirkbride stilling pond, figure 3.141. The trend was not so obvious with the Extended stilling pond, figure 3.147 When the data from both sites was plotted on one graph there was no obvious trend between the two parameters, figure 3.153. The faeces mass against flowrate graphs for the two sites, figures 3.123 and 3.129, and the combined graph, figure 3.135, show a lot of scatter of the data points making it difficult to establish trends. The graphs of screen retention efficiency against the other parameters, figures 3.78, 3.87, 3.93, 3.102, 3.108 and 3.117, and have not produced any useful information for this material.

Fine Paper (Toilet Paper): This material was of paper origin, most probably toilet paper and the cotton inners of sanitary products. It is this material which causes the problems encountered with the 'ragging up' of equipment. The Copasacs in the spill chambers of both combined sewer overflow sites were completely blinded with this material on occasion. During classification of the samples, it was possible to peel a proportion of this paper from the Copasac, however, the majority of the material adheres to the Copasac and becomes woven between the plastic mesh making it impossible to separate the two. These particular gross solids become shredded within the sewerage system into a very fine material which is suspended in the flow. Once discharged to the receiving watercourse they were observed to wrap around vegetation and re-form into larger aesthetic pollutants. It was found that a small proportion of this material would wrap itself around the screen bars at the Sharpe and Kirkbride stilling pond. The screen retained on average 10% of the total amount of material presented to it. In contrast, the Extended stilling pond retained none of this particular material presented to it. There seems to be no explanation for this. However, the screen at the Sharpe and Kirkbride stilling pond CSO is a much older screen than the screen at the Extended stilling pond CSO. Consequently wearing of the screen bars may have some bearing on different gross solids retention. The average mass of fine paper collected at the two overflows differs quite significantly with the Sharpe and Kirkbride stilling pond overflow having an average mass of 1447 grams compared with 736 grams for the Extended stilling pond overflow. The average percentages of overall sample mass for this fine paper material were 51% for the Sharpe and Kirkbride stilling pond and 28% for the Extended stilling pond CSO. The bar charts of fine paper mass against mean overflow intensity and maximum flowrate, figures 3.35, 3.46, 3.58 and 3.69, illustrate that this material is continually transported within the sewerage system, its transportation not relying on a threshold velocity of flow. The scatter graphs plotted of these three parameters, figures 3.142, 3.148, 3.124 and 3.130, show that the mass of fine paper increases as the mean overflow intensity increases and as the maximum flowrate increases. This is true at both CSO sites and can also be seen on the graphs where the data of both sites is plotted together, figures 3.154 and 3.134. The screen retention efficiency of fine paper was found to be 0% at the Extended stilling pond overflow so the graphs using this parameter have not been plotted. The Sharpe & Kirkbride stilling pond graphs and the combined graphs of screen retention efficiency against the other three parameters have not produced any useful trends, figures 3.79, 3.88, 3.94, 3.103, 3.109, and 3.118.

Leaves: The percentage of leaves in the sewerage system depends on the season and also the catchment characteristics. Leaves are not considered by the general public to be an aesthetic pollutant because the source of entry into the river is not always known. A leaf could have fallen straight into the river from a tree rather than been discharged from a CSO along with other gross solids. A large proportion of the leaves examined from the CSOs were coated with faeces or stuck together in a bundle with it. However, most of the leaves found like this were retained by the screens. The Sharpe and Kirkbride stilling pond retained on average 28% of the leaf material presented to it compared with an average of 26% for the Extended stilling pond. The average percentages of overall sample mass were 10% for Sharpe and

Kirkbride stilling pond CSO and 45% for Extended stilling pond CSO. The different catchment characteristics and the time of year when monitored probably account for this large difference in the percentage of overall sample mass for the two sites. The Extended stilling pond CSO catchment area appeared to have a higher proportion of tree-lined roads and open grassed areas than the Sharpe and Kirkbride stilling pond CSO catchment area and was also monitored during Autumn. The bar charts for leaves mass against mean overflow intensity and maximum flowrate for the Sharpe & Kirkbride stilling pond, figures 3.36 and 3.59, indicate that leaves are only transported within the sewerage system once a certain velocity of flow has been reached. However, this does not hold true for the Extended stilling pond where the bar charts, figures 3.47 and 3.70, show leaves are continually transported within the system regardless of the velocity of flow. This could be due to the catchment characteristics and the time of year of monitoring of each site. Both CSO sites show an increasing mass of leaves with both mean overflow intensity and maximum flowrate, figures 3.143, 3.149, 3.125 and 3.131 when the parameters are plotted as a scatter plot. A relationship between the parameters is not so easily seen with the combined graphs, figures 3.137 and 3.155 The plots of screen retention efficiency against the other parameters, figures 3.80, 3.89, 3.95, 3.99, 3.104, 3.110, 3.114 and 3.119, did not reveal any obvious trends in the data except for the Extended stilling pond graph of screen retention efficiency against maximum flowrate, figure 3.84, where a definite relationship can be seen. This indicates that as the maximum flowrate increases so too does the screen retention efficiency.

Paper Towels : This material was much thicker than the fine paper collected and appeared to be more like the paper towels provided in toilets for hand drying. Similar proportions of the material were found at both the CSO sites with the average percentage of the total sample mass being 5.3% at the Sharpe and Kirkbride stilling pond CSO compared to 4.4% at the Extended stilling pond CSO. However, there was a large variation in the percentage retained between the two sites with the Sharpe and Kirkbride stilling pond retaining only 56.6% whereas the Extended stilling pond retained 100%. There appears to be no explanation for this. As with fine paper this material appears to be continually in the flow and does not require a threshold flowrate to transport it through the sewerage system. This can be seen with figures 3.39, 3.49, 3.62 and 3.72. A relationship seems to exist between paper towel mass and mean overflow intensity, figures 3.144, 3.150 and 3.156, and also between paper towel mass and maximum flowrate, figures 3.126, 3.132 and 3.138. A greater mass of paper towels is presented to the screen with increasing mean overflow intensity and maximum flowrate. There were no obvious trends between screen retention efficiency and the other three parameters for the Sharpe & Kirkbride stilling pond, figures 3.81, 3.96 and 3.111, these graphs were not plotted for the Extended stilling pond since there was a 100% screen retention efficiency for all the paper towels collected.

Sanitary Towels : Whole sanitary towels and the plastic shells of sanitary towels were collected in the samples from both combined sewer overflows. A proportion of the sanitary towels collected were the thinner and smaller panty liners but the percentage of each was not investigated. The majority of the sanitary towels found at both sites were whole towels, very few plastic shells were found, again the percentage of each was not investigated. There was no evidence of plastic backing strips (the strip removed from the adhesive tape of sanitary products) at either combined sewer overflow site. Similar proportions of the material were found at both the CSO sites with the average percentage of the total sample mass being 16% at the Sharpe and Kirkbride stilling pond CSO compared to 15% at the Extended stilling pond CSO. Both screens investigated screened the sanitary products reasonably efficiently. The Sharpe and Kirkbride stilling pond retained on average 73.7% of the sanitary towels presented to the screen. The Extended stilling pond retained on average 92% of the material presented to the screen. The screens at both combined sewer overflow sites retain at least three quarters of the sanitary towels presented to them. Figures 3.41, 3.50, 3.64 and 3.73 demonstrate that sanitary towels are constantly transported within the sewerage system. The mass of sanitary towels was also found to steadily increase with increasing mean overflow intensity and maximum flowrate, figures 3.127 and 3.145, at the Sharpe & Kirkbride stilling pond. This was not the case at the Extended stilling pond. A gradual rise was seen in sanitary towel mass with increasing flowrate, figure 3.133, but there was no clear trend with mean overflow intensity, figure 3.151. The combined graphs for these parameters show a wide scatter of the data points. The graphs of screen retention efficiency against the other parameters did not produce any useful information.

Sweet Wrappers : The majority of the sweet wrappers identified at both CSO sites were plastic material, being mainly crisp packets or chocolate bar wrappers. As with leaves they are not considered to be an aesthetic pollutant from a sewage source although they may be considered a litter pollutant. Again, like leaves they were often found stuck to faeces or with faeces adhering to them. The average percentage of overall sample mass was 3% for the Sharpe and Kirkbride stilling pond compared with 0.5% for Extended stilling pond. The Sharpe and Kirkbride stilling pond CSO retained on average 69% of the sweet wrappers presented to the screen and Extended stilling pond CSO retained 100%. The bar charts of sweet wrapper mass against mean overflow intensity and maximum flowrate, figures 3.42, 3.51, 3.65 and 3.74, indicate that the material is continually transported within the sewerage system regardless of the velocity of flow.

Tampons : Initially tampons were categorised with sanitary towels with just the number of tampons collected being noted, however, it was decided to separate the two into different categories to enable a comparison between sanitary products to be made. The majority of the tampons collected were applicator tampons, very few non-applicator tampons were found. Cardboard tampon applicators were not collected at either combined sewer overflow site and the plastic tampon applicators now available had not been launched on the market when the two CSO's were monitored. The average percentage of overall sample mass was 1.5% for the Sharpe and Kirkbride stilling pond compared with 3% for the Extended stilling pond. The Sharpe and Kirkbride stilling pond retained on average 85% of the tampons presented to the screen and the Extended stilling pond retained 98%. Figures 3.43, 3.52, 3.66 and 3.75, are the bar charts for tampon mass against mean overflow intensity and maximum flowrate. The transportation mechanism for tampons is not easily discernible from these charts.

Other Materials : The cloth found at the Sharpe and Kirkbride stilling pond CSO was of a fabric/material origin. The plastic collected at the Sharpe and Kirkbride stilling pond CSO was of a litter origin being mainly plastic bottle tops. The disposable nappies were not whole nappies but pieces of the plastic outer shell. The clear plastic wrappers collected at the Extended stilling pond were the packaging off cigarette packets and again of a litter origin. The miscellaneous absorbent material appeared to be of a paper origin. The paper seemed to have wound itself together into a hard, solid mass which could not be separated, but which was very lightweight and able to float. The miscellaneous non-absorbent material collected only at the Sharpe and Kirkbride stilling pond CSO appeared to be of a fat origin and was quite dense and sank in the flow. Again the material could not be easily separated.

Table 3.12 summarises the mean gross solids composition for the combined sewer overflow sites and their respective screen retention efficiencies.

Table 3.12 Mean Efficiency of Combined Sewer Overflow Screens for Individual Materials

	Sharpe & Kirkbride Stilling Pond Overflow		Extended Stilling Pond Overflow	
Flow Range	0-85 l/s		0-50 l/s	
Mean Sample Mass	2855 g		2600 g	
Gross Solids	Percentage of Overall Sample (%)	Retention Efficiency (%)	Percentage of Overall Sample (%)	Retention Efficiency (%)
Fine Paper	51	10	28	0
Leaves	10	28	45	26
Paper Towels	5	57	4	100
Sanitary Towels	16	73	15	92
Sweet Wrappers	2	69	1	100
Tampons	2	85	2	98
Other	14	N/A	5	N/A

Sharpe and Kirkbride stilling pond: The average efficiency of the mechanically raked D-screen with 12 mm bars and 15 mm spacings at this combined sewer overflow site was found to be 36% ± 14.24%. The mean sample mass collected was 2855 grams and the range of flows examined were 0 l/s to 85 l/s. The graph of total gross solids mass presented to the screen against mean overflow intensity, figure 3.140, indicates that there is a relationship between the two. As the mean overflow intensity increases so does the mass of gross solids presented to the screen. There also appears to be a trend between total gross solids mass and maximum flowrate, figure 3.122, although this is not as clearly defined. The graphs of screen retention efficiency against total gross solids mass, mean overflow intensity and maximum flowrate figures 3.92, 3.107 and 3.77, have not produced any discernible relationship. There were no cotton bud sticks found in any of the samples for any of the storm events and only seven condoms were collected during the whole 7 month monitoring period. The other materials collected at the Sharpe and Kirkbride stilling pond were cloths, disposable nappies, miscellaneous absorbent (paper origin), miscellaneous non-absorbent (fat origin) and plastic. When the total mass of condoms collected was plotted against mean overflow intensity a sudden sharp step was observed when the mean overflow intensity reached 2.47 m^3/min, figure 3.32, indicating that condoms are only transported within the sewerage system once a threshold velocity of flow is reached. A similar step was also seen with the plot of condom mass against maximum flowrate, figure 3.55. This phenomenon was also observed with disposable nappies, figures 3.33 and 3.56. The transportation mechanism for cloth and miscellaneous non-absorbent material was not clearly defined in the plots, figures 3.31, 3.38, 3.54, and 3.61. The miscellaneous absorbent material seemed to be carried continually in the flow although this was not conclusive from the plots, figures 3.37 and 3.60.

Extended Stilling Pond: The average efficiency of the mechanically raked D-screen with 12 mm bars and 15 mm spacings at this combined sewer overflow site was found to be 33% ± 15.37%. The range of flows examined were 0 l/s to 50 l/s and the mean sample mass was found to be 2600 grams. A relationship was observed between the plot of total gross solids mass and maximum flowrate through the screen, figure 3.128, which indicated that there was an increase in the mass of gross solids with increasing flowrate. A relationship between total gross solids mass and mean overflow intensity, figure 3.146, was not as discernible, although there did appear to be a trend indicating gross solids mass increases with mean overflow intensity. The graph of screen retention efficiency against mean overflow intensity, figure 3.113, showed no obvious trend. The plot of screen retention efficiency against maximum flowrate, figure 3.83, showed increasing screen retention efficiency with increasing maximum flowrate. No clear relationship could be seen with the graph of screen retention efficiency against total gross solids mass, figure 3.98. During the whole 2½ month monitoring period no cotton bud sticks or condoms appeared in any of the samples collected. The other materials which appeared at the Extended stilling pond were clear plastic wrappers, miscellaneous absorbent (paper origin) and tea bags. A threshold maximum flowrate was observed with the plots of gross solids mass against maximum flowrate for the clear plastic wrappers, miscellaneous absorbent material and the tea bags, figures 3.67, 3.71 and 3.76. The threshold flowrate being 0.12 m^3/sec for the two former materials and 0.19 m^3/sec for the latter. This was not seen when the masses were plotted against the mean intensity of overflow, figures 3.44, 3.48 and 3.53. A packet of hypodermic syringes was also found in one sample but these have not been included in the analysis as they were considered unique to the sample. They were, however, retained by the screen and not passed to the receiving watercourse.

3.9.2 Sewage treatment works

The main materials presented to the screens at the sewage treatment works were:

Condoms

Faeces

Fine Paper (Toilet Paper)

Grit

Plastic Shells of Sanitary Towels

Tampons

Thick Paper Towels

Vegetable Matter

Whole Sanitary Towels

The average efficiency for the inclined bar screen was found to be 52% ± 15.52%, once the gap at the base of the screen had been sealed, and the average efficiency for the 25 mm D-screen was found to be 18% ± 13.32%. The two screens handled flowrates ranging from 0 l/s to 150 l/s. Graphs were plotted of screen retention efficiency against the mean flowrate through the screen, figures 3.158, 3.159, 3.163 and 3.164, and for screen retention efficiency against the total mass of gross solids presented to each screen, figures 3.168, 3.169, 3.173 and 3.174. Trends were not discernible for either screen for screen retention efficiency against mean flowrate. Similar graphs were produced for fine paper, sanitary towels and tampons for both screens, figures 3.160 to 3.162 and figures 3.165 to 3.167, but no discernible trends were established. The graph of retention efficiency against total gross solids mass for the D-screen showed that screen retention efficiency decreased with increasing gross solids mass in a series of curves. However, the same plot for the inclined bar screen showed increasing screen retention efficiency with increasing gross solids mass. Similar graphs were produced for fine paper, sanitary towels and tampons for both screens, figures 3.170 to 3.172 and figures 3.175 to 3.177, but no discernible trends were established. Graphs were also plotted of gross solids mass against mean flowrate for both the total mass of gross solids and for individual materials, figures 3.178 to 3.192. There seems to be a relationship between these two parameters, indicating that the mass of gross solids increases as the mean flowrate through the screen increases. The results from the D-screen are more conclusive than those from the inclined bar screen.

Condoms: A significant increase in the number of condoms observed was noted at the sewage treatment works. However, even with the increased number of the condoms the majority detected were retained by both screens indicating that the evidence of condoms along river banks probably do not originate from combined sewer overflow discharges.

Fine Paper (Toilet Paper): A significant difference was observed between the amount of this material the two screens retained. The inclined bar screen retained 37% of this material which was raked off the screen in a large, wet mass usually containing some vegetable matter and grit. The D-screen retained only 7% of this material and the Copasac downstream was considerably more furred up with this material. A test was performed at the sewage treatment works to investigate whether the gross solids passing through the inclined bar screen would adhere to a tree branch as evident along watercourses downstream of overflow discharges. A tree branch was held in the flow downstream of the inclined bar screen. It was found that the fine paper particles in suspension coalesce then adhere to each individual tree branch. This would indicate that if 6 mm inclined bar screens were the sole means of aesthetic pollutants control for combined sewer overflows, fine paper would still be visible on river banks at the discharge points of the overflows. The average percentage of overall sample mass was 81% for the inclined bar screen compared with 78% for the D-screen. The inclined bar screen retention efficiency for fine paper was found to be on average 37% compared with only 7% for the D-screen.

Grit: Grit was not found to be a problem when investigating the D-screen at the works. However, it became clear when examining the inclined bar screen that grit settlement at the base of the upstream side of the screen was a problem. The hinged plate used to seal the gap at the base of the inclined bar screen increased the depth of flow upstream of the screen. The increased depth of flow upstream of the screen resulted in reduced velocities of flow which allowed grit to settle infront of the screen. The flow through the screen is unable to remove this sedimentation. This would not be a major problem if there was a continuous flow through the screen but in combined sewer overflows the screens only operate during a storm event and the sedimentation infront of the screen could prevent the raking mechanism from operating. The grit settlement in the inclined bar screen channel was the cause of the shear pin breaking in the screen motor at the treatment works. Consequently, the inclined bar screen had to be cleared of grit every site visit before the raking mechanism could be operated.

Sanitary Towels: A higher number of plastic shells of sanitary towels were found at the treatment works when compared with the amount collected at the combined sewer overflow sites. As well as the plastic shells, the plastic backing strips were also detected as were the plastic wrappers that a number of these products are packaged in. Both screens at the sewage treatment works were efficient in retaining these products, with the inclined bar screen retaining on average 97% of the sanitary towels presented to it and the D-screen retaining on average 95%. The sanitary towels represented on average 8% of the overall sample mass collected from the inclined bar screen tests and on average 16% of the total sample mass from the D-screen tests. The mean sample mass of the inclined bar screen was nearly twice as large as that of the D-screen. This accounts for the percentage of sanitary towels in the sample composition of the inclined bar screen being half the percentage of the sample composition of the D-screen.

Tampons: The number of tampons collected at the sewage treatment works was higher than those found at the CSO sites. The inclined bar screen retained on average 99% of the tampons presented to it, with an average of 98% for the D-screen. It was found that for both screens, tampons represented 5% of the overall sample mass. There was, however, evidence of plastic tampon applicators at the sewage treatment works and a number of these did pass through the D-screen.

Vegetable Matter: The fine screen was able to retain and rake very small vegetable matter most notably peas and sweetcorn. This material had not previously been observed at the combined sewer overflow sites and it was evident that the D-screen at the sewage treatment works was unable to retain any of this material.

Other Materials: Cotton bud sticks were found at the sewage treatment works, both in the gross solids samples retained by the screens and those passed through the screen. The amount of leaves detected in the samples was notably less than the amount found at the combined sewer overflow sites even though the monitoring period was during autumn. A small number of paper towels were retained by the inclined bar screen but none were found in any of the D-screen samples. The number of sweet wrappers found in the samples was also a lot less than the number detected at the CSO sites. Frogs, slugs and worms (live and dead) were also found.

Table 3.13 summarises the mean gross solids composition for the sewage treatment works screens and their respective screen retention efficiencies.

Table 3.13 Mean Efficiency of Sewage Treatment Works Screens for Individual Materials

	6 mm Inclined Bar Screen		25 mm D-Screen	
Flow Range	0-125 l/s		0-115 l/s	
Mean Sample Mass	1781 g		997 g	
Gross Solids	Percentage of Overall Sample (%)	Retention Efficiency (%)	Percentage of Overall Sample (%)	Retention Efficiency (%)
Fine Paper	81	37	78	7
Paper Towels	1	100	0	N/A
Sanitary Towels	8	97	16	95
Tampons	5	99	5	98
Other	5	N/A	1	N/A

3.10 Comparison between CSO and STW bar screens

The spacing of screen bars significantly affects the screen efficiency. This can be seen from the screens examined in the field and their respective efficiencies as shown in table 3.14. The finer the screen the more efficient the screen at retaining gross solids. However, sample analysis has shown that materials larger than the actual screen spacing are regularly passed through the screens. Several factors seem to influence this:

- The orientation of the material as it is presented to the screen.
- The length of time the material remains on the screen before being raked off.
- The force of the flow through the screen
- The nature of the actual material, whether it is a solid or hard material or whether it is a flimsy or pliable material.

These factors could account for the large variations in the screen efficiencies obtained for all the screens examined.

Table 3.14 Screen Retention Efficiency Variation

Site	Screen bar spacing (mm)	Mean Efficiency (%)	Standard Deviation (± %)
STW D-Screen	25	18	13.32
Extended stilling pond	15	33	15.37
S & K stilling pond	15	36	14.24
STW inclined bar Screen	6	52	15.52

The mean efficiencies of these four screens are discussed further in the concluding discussion of chapter 4.

CHAPTER 4 TESTING OF SCREEN MESHES

4.1 Introduction

A series of tests were performed in the field and in the laboratory to determine the effectiveness of modern screening media at handling aesthetic pollutants. The performance and efficiency of five different 6 mm mesh screen types at retaining aesthetic pollutants was determined by testing at a sewage treatment works inlet. Comparative tests were also carried out on all five screen types at a different works inlet to ensure the performance and efficiencies obtained were not influenced by the inlet configuration or the sewage entering the works. Laboratory tests on the five screens were also conducted to establish whether simulated laboratory tests could provide similar results to those obtained in the field, and to try to establish head loss and further explain the efficiencies determined in the field tests. The settling velocities of various materials commonly found in sewage has also been investigated in the laboratory using a settling column.

Table 4.1 Screen Specifications

	hole size (mm)	% open area	configuration	thickness (mm)
Plastic Mesh Sack (Copasac)	6.0 x 6.0	74	square	1.0
Polyurethane Moulded Round	6.0 dia.	49	60° offset	9.0
Steel Perforated Round	6.4 dia.	43	60° offset	0.7
Steel Perforated Square	6.0 x 6.0	62	square	0.7
Steel Perforated Square Staggered	6.0 x 6.0	52	stagger	0.7

The steel perforated materials chosen enabled a direct comparison to be made between different hole patterns by using the same material composition and thickness. The round polyurethane mesh allowed comparative tests to be done on a screening media of different material composition and thickness.

4.2 Field Tests

Several sewage treatment works (STW) were visited within travelling distance of Sheffield Hallam University to locate two suitable testing sites. Long Lane STW was selected as one of the test sites because access had already been granted to allow the tests to be carried out at the works. Previous experience of testing at the site had already been gained during the inlet bar screen monitoring work, so equipment locations were already established. This reduced the time taken to install equipment and develop a test methodology. Holbrook STW was chosen as the seond site. The works is South East of Sheffield and is served by Halfway, Killamarsh and Mosborough. The catchment area of the STW is predominately residential. The two sites were visited twice weekly and between six and eight individual tests were carried out during each visit. Testing commenced at the beginning of November 1994 and four of the five screen meshes had been evaluated by the middle of December 1994. A delay in obtaining the polyurethane screen mesh resulted in this screen mesh being tested at the beginning of March 1995.

4.2.1 Methodology

The five screen meshes were tested individually. Each screen mesh was inserted into the flow for a set period of time. A dual capture system, consisting of two 6 mm plastic mesh sacks (Copasacs) spaced apart and placed behind the test mesh, was used to collect any gross solids passing through the mesh during the test. A third Copasac was not deemed necessary since the mass of gross solids caught by the second Copasac was negligible when compared with the masses retained by the mesh and the first Copasac. Three rectangular steel frames were manufactured for each site to support the screen meshes and the Copasacs during each test. The first frame held the screen mesh under test, whilst the other two screen frames had a sheet of one inch mesh fastened to them onto which the Copasacs were attached.

The Copasacs were cut and opened out so only a single layer of plastic mesh covered each frame.

Three sets of steel runners were installed in the rectangular channel downstream of the D-screen at Long Lane STW. These guides allowed the three steel screen frames to be manually inserted into the flow so a test could be carried out in the field using real sewage. A flow monitor was installed in the channel downstream of the steel guides, in the same position as the one used for the bar screen monitoring, so that the flow rate through the various screen meshes could be recorded during each test. During testing the flow monitor recorded the depth and velocity of flow every 10 seconds. On each site visit the transducer was de-ragged prior to testing and manual depth readings were taken both before testing and after testing was complete, to check the accuracy of the equipment. By doing these checks any problems with the monitor could be established immediately and rectified.

For each individual test, the three frames were inserted simultaneously into the flow each one being held vertically in the channel by the steel guides, figure 4.1. The screen mesh under test was inserted into the first set of guides nearest the 25 mm D-screen with the two Copasac collection frames behind it. The frames were then left in position until the test screen became partially blinded, and all three screen frames were then removed simultaneously. The time taken for each test screen to partially blind was approximately one minute. By inserting two 6 mm Copasac screens behind the test screen it was possible to measure the efficiency of the test screen mesh at retaining gross solids. The first Copasac captured any gross solids which passed through the test screen and the second Copasac collected any gross solids which escaped through the first Copasac. The testing was carried out downstream of the 25 mm D-screen so the gross solids retained by the D-screen during each test were also collected. It was assumed that all these gross solids would have been retained by the test screen mesh if the D-screen installation was not there. The gross solids collected from the D-screen were included in the test screen mesh sample and were separated

Figure 4.1 Long Lane STW : Screen mesh frames held in position between steel guides

and classified into individual material prior to being weighed on a set of electronic scales.

Following removal from the channel the three frames were stood vertically to drain, the material was then separated and classified into individual material for weighing, figure 4.2. Once the larger solids had been removed from the gross solids retained by the three screens the fine paper remaining on the test screen was scraped off using a paint scraper and the liquid squeezed out before being weighed, figure 4.3. The Copasacs were then removed from their frames and wrung out by hand before being weighed. The weight of the Copasac was deducted from the total weight to obtain the net material weight.

During each test, depth measurements were taken upstream of the test screen mesh, between each steel frame and also downstream of the second Copasac frame, figure 4.4. This enabled the head losses for each screen mesh to be calculated and in addition to this an overall head loss for the screening system could be determined.

At Holbrook STW the inlet is gravity fed. The flow enters a rectangular channel before passing through a 6 mm inclined bar screen. As with Long Lane STW the screened flow passes into primary settling tanks via a rectangular channel. Three sets of steel runners similar to those used at Long Lane STW were installed in the inlet channel to hold the steel frames vertically in the flow during testing. Unlike the installation at Long Lane STW, the guides were located upstream of the inclined bar screen, figure 4.5. As with the testing at Long Lane STW the screens were manually inserted into the flow for each test. A flow monitor was installed in the rectangular channel downstream of the inclined bar screen to record the depth and velocity of flow through the screens during each test. Again on each site visit the transducer was cleaned before any testing took place and the depth of flow measured to check the reliability of the flow monitor.

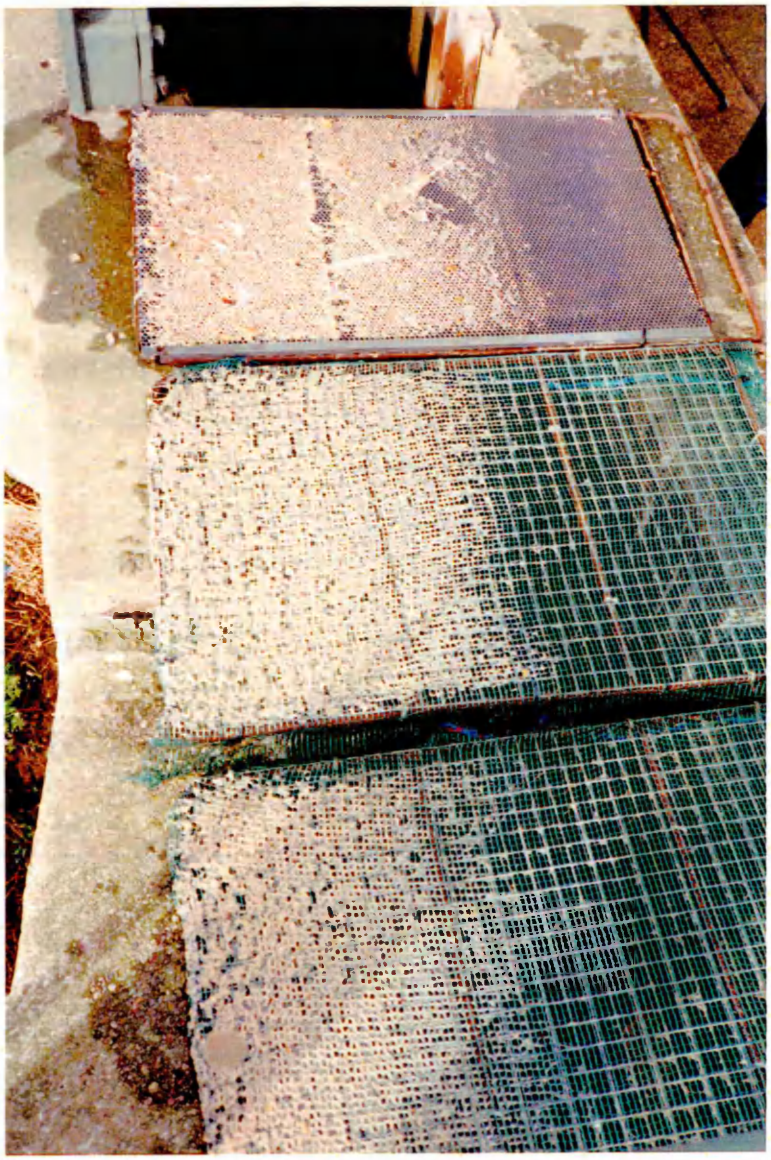


Figure 4.2 Long Lane STW: Screen mesh frames immediately after removal from flow

Figure 4.3 Test screen mesh after being cleaned with a paint scraper

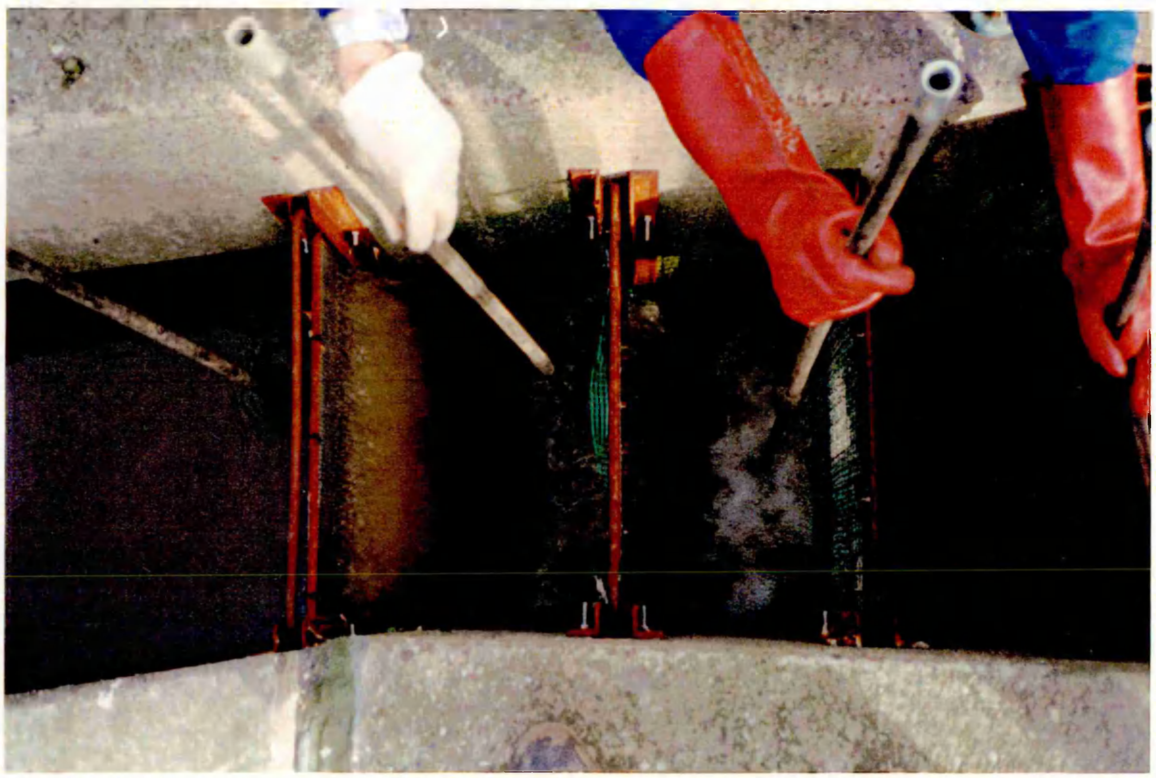


Figure 4.4 Recording depth of flow between each screen frame during test

Figure 4.5 Holbrook STW: Screen mesh frames held in position between steel guides

The testing method used at Holbrook sewage treatment works was the same as Long Lane STW except that the material collected by the inclined bar screen did not influence the material collected during testing as the test screens were inserted into the flow upstream of the inlet screen; figure 4.6 and 4.7.

Problems with the flow monitoring equipment were experienced during testing at both STWs. The problem was initially thought to be drifting of depth readings commonly found with this type of monitoring equipment. The transducer was removed from site, cleaned down and set in a tank of water in the laboratory. Monitored depth readings were then compared with static depth measurements. The recorded data was shown to be correct. The problem was investigated further and traced to the small hole underneath the transducer head where the pressure diaphragm used for depth measurement is located. This hole became blocked when severe ragging of the transducer head occurred and the flow monitor recorded false depth readings. Access to the bottom of the transducer head for cleaning was limited when fixed on the channel bed. Consequently, two sets of data from Long Lane STW and one set of data from Holbrook STW had no flow information because of this problem. The transducer heads were thoroughly cleaned and as much debris as possible removed from underneath the monitor during subsequent site visits.

4.2.2 Blinding test

A blinding test was carried out at Holbrook STW to investigate the rate of screen mesh blinding and the subsequent effect on the head loss of the screen mesh. The 6.0 mm round polyurethane test screen was inserted into the flow for successive 15 second intervals and then removed for weighing and photographing. The whole screen mesh and screen frame were weighed at the start of testing and at the end of each interval to obtain the weight of material retained each time the screen mesh was inserted into the flow. The head loss was recorded by measuring the depth of flow either side of the screen mesh during each test. After one minute the testing time was

Figure 4.6 Screen mesh frames in position at Holbrook STW

Figure 4.7 Holbrook STW: Screen mesh frames immediately after removal from flow

Figure 4.8 Blinding test: After 60 secs

Figure 4.9 Blinding test: After 90 secs

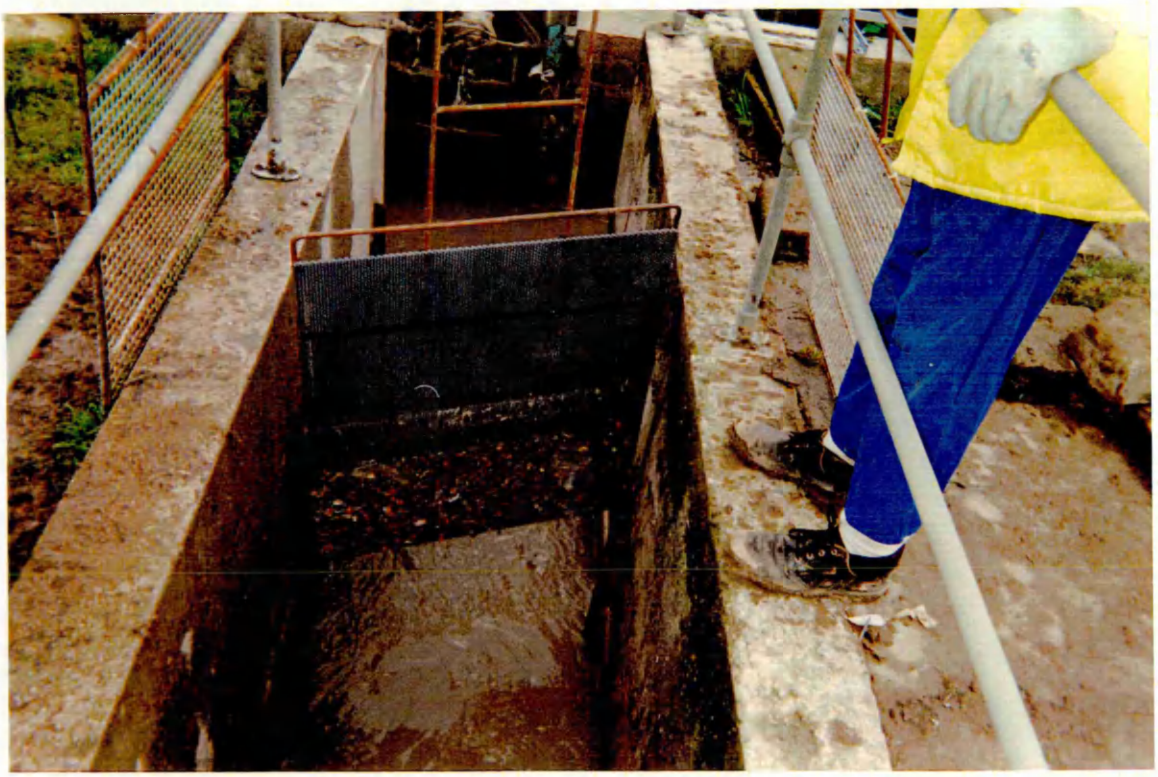


Figure 4.10 Blinding test: After 120 secs

Figure 4.11 Blinding test: After 180 secs

Figure 4.12 Blinding test: After 240 secs

Figure 4.13 Blinding test: After 300 secs

Figure 4.14 Test screen mesh after removal from flow after 300 secs

Figure 4.15 Test screen mesh after 300 secs scraped clean

Figure 4.16 Screen mesh after cleaning

extended to every 30 seconds and after two minutes to every minute. Figures 4.8 to 4.16 are the photographs taken during the blinding test. Unfortunately, the photographs taken of the first three tests were faulty so the figures start at the 60 second test.

4.2.3 Analysis

The efficiency of each screen mesh was calculated for total gross solids and also for individually classified materials, e.g. sanitary towels, tampons, cotton bud sticks, fine paper etc. The efficiency definitions used for the overall screen retention efficiency and the screen retention efficiency for individual materials were the same as those used in 3.7.1. The flow rate given for each test is the Mean Flow Rate through the screen during each test.

4.2.4 Results of field tests

Table 4.2 shows the mean screen retention efficiencies for each of the five screen meshes for both sewage treatment works. The mean screen head loss for each of the five screen meshes at both sites is given in table 4.3. The mean flow rate through each screen mesh is shown in table 4.4. Tables 4.5 and 4.6 show the mean composition of the gross solids collected on each test screen mesh for both sewage treatment works. For example at Holbrook sewage treatment works the mean percentage of fine paper collected on the 6.4 mm perforated round hole screen was 97.2% of the total gross solids collected on the screen. Table 4.7 gives the results of the screen mesh blinding test using the polyurethane mesh. The retention efficiency of each individual material together with the mean composition of gross solids collected for each screen mesh at both sewage treatment works are presented in tables 4.8 and 4.9.

Table 4.2 Mean Screen Retention Efficiency

Screen Material	Holbrook STW (%)	Long Lane STW (%)
6.0 mm Copasac	49	64
6.4 mm Round Perforated	58	64
6.0 mm Square Staggered Perforated	49	55
6.0 mm Square Perforated	52	58
6.0 mm Round Perforated Polyurethane	48	59

Table 4.3 Mean Screen Head Loss

Screen Material	Holbrook STW (mm)	Long Lane STW (mm)
6.0 mm Copasac	113	195
6.4 mm Round Perforated	49	128
6.0 mm Square Staggered Perforated	82	106
6.0 mm Square Perforated	106	294
6.0 mm Round Perforated Polyurethane	60	113

Table 4.4 Mean Flow Rate through Screens

Screen Material	Holbrook STW (l/s)	Long Lane STW (l/s)
6.0 mm Copasac	69	75
6.4 mm Round Perforated	76	80
6.0 mm Square Staggered Perforated	53	89
6.0 mm Square Perforated	61	82
6.0 mm Round Perforated Polyurethane	115	102

Table 4.5 Holbrook Sewage Treatment Works: Sample Composition

Material	6.0 mm Copasac (%)	6.4 mm Perforated Round (%)	6.0 mm Perforated Square Staggered (%)	6.0 mm Perforated Square (%)	6.0 mm Perforated Round Polyurethane (%)
Cotton Bud Sticks	0.5	0.2	0.1	0.2	0.3
Fine Paper etc.	96.9	97.2	97.1	96.3	97.1
Sanitary Towels	2.3	2.6	2.6	2.4	2.6
Tampons	0.3	0.0	0.2	1.1	0.0

Table 4.6 Long Lane Sewage Treatment Works: Sample Composition

Material	6.0 mm Copasac (%)	6.4 mm Perforated Round (%)	6.0 mm Perforated Square Staggered (%)	6.0 mm Perforated Square (%)	6.0 mm Perforated Round Polyurethane (%)
Cotton Bud Sticks	0.2	0.1	0.3	0.3	0.5
Fine Paper etc.	85.4	79.3	82.6	91.0	87.0
Sanitary Towels	10.9	13.9	13.6	5.2	6.7
Tampons	3.5	6.7	3.5	3.5	5.8

Table 4.7 Screen Blinding Test with Polyurethane Screen

Time (secs)	Head Loss (mm)	Material Weight (kg)
15	30	0.5
30	40	0.6
45	50	0.7
60	70	0.9
90	90	1.1
120	130	1.1
180	185	1.2
240	195	1.5
300	230	1.6

4.2.5 Discussion of field tests

Of the five screens tested at the sewage treatment works' the 6.0 mm round perforated polyurethane screen was found to be the hardest screen to manually clean. The thickness of the material created a honeycomb which held water and allowed solids being scraped from the screen face to fall into the holes and become trapped. The paint scraper being used to clean the mesh had to be used in a circular motion to lift the fine paper away from the holes. The fine paper could then be pulled together into one mass for draining and weighing. Even using this method of cleaning a small percentage of the fine paper still remained on the screen mesh face and this could not be removed with the paint scraper or by trying to pick the pieces off by hand.

The nature of the gross solids collected was found to be the same at each sewage treatment works, however, the composition of each sample of gross solids collected for each test was different for the two works, tables 4.5 and 4.6. Long Lane STW had a much higher percentage of sanitary towels and tampons than Holbrook STW. Several factors could influence this, the size and make-up of the drainage area, the way the sewage enters the works, by gravity or pumped, the social mix of the catchment, or the age of the sewerage system. Long Lane STW is served by an older system than Holbrook STW. However, the material composition at each sewage treatment works was found to be consistent for the five screens tested allowing a comparison of the screens to be made.

The mean flow rate through the screens was not as consistent, the mean flow rate during the polyurethane screen tests being almost twice as high as the other screens at Holbrook STW and almost 1½ times higher at Long Lane STW, table 4.4. This was due to seasonal variations in the weather. The other four screens were tested during November and December 1994, the polyurethane screen was not tested until March 1995 due to a delay obtaining the screen mesh. These differences in mean flow rate may influence the screen retention efficiency.

The 6.4 mm round perforated steel screen mesh and the 6.0 mm plastic mesh Copasac were found to have the highest retention efficiency at Long Lane sewage treatment works, table 4.2. However, the plastic mesh Copasac had a greater fine paper retention efficiency than the round perforated steel screen mesh. The 6.4 mm round perforated steel screen mesh was found to have the highest overall retention efficiency, the highest fine paper retention efficiency and the lowest mean head loss at Holbrook sewage treatment works, table 4.3.

Staggering holes does not appear to increase the retention efficiency of screens. The square hole screen mesh performed better than the staggered square hole screen mesh for individual material retention efficiency and overall retention efficiency. However, the square hole screen mesh had a higher mean screen head loss at both

Table 4.8 : Holbrook Sewage Treatment Works

Material	6.0 mm Copasac			6.4 mm Perforated Round			6.0 mm Perforated Square Staggered			6.0 mm Perforated Square			6.0 mm Perforated Round Polyurethane		
	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)
Cotton Bud Sticks	0.5	100	0	0.2	100	0	0.1	100	0	0.2	100	0	0.3	100	0
Fine Paper etc.	96.9	48	52	97.2	56	44	97.1	47	53	96.3	50	50	97.1	47	53
Sanitary Towels	2.3	100	0	2.6	100	0	2.6	100	0	2.4	100	0	2.6	100	0
Tampons	0.3	100	0	0	100	0	0.2	100	0	1.1	100	0	0	100	0
Total	100	49	51	100	64	36	100	49	51	100	52	48	100	48	52

Table 4.9 : Long Lane Sewage Treatment Works

Material	6.0 mm Copasac			6.4 mm Perforated Round			6.0 mm Perforated Square Staggered			6.0 mm Perforated Square			6.0 mm Perforated Round Polyurethane		
	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)	Sample %age	Retained (%)	Passed (%)
Cotton Bud Sticks	0.2	100	0	0.1	100	0	0.3	100	0	0.3	100	0	0.5	100	0
Fine Paper etc.	85.4	57	43	79.3	55	45	83.6	49	51	91	51	49	87	48	52
Sanitary Towels	10.9	100	0	13.9	100	0	13.6	100	0	5.2	100	0	6.7	100	0
Tampons	3.5	100	0	6.7	100	0	3.5	100	0	3.5	100	0	5.8	100	0
Total	100	64	36	100	64	36	100	55	45	100	55	45	100	59	41

sewage treatment works compared with the square staggered hole screen mesh. The square screen also has a higher percentage open area than the staggered square screen mesh.

Graphs were plotted of head loss and material mass with time, figure 4.17, for the polyurethane screen blinding test. Log plots were also produced to investigate the relationship between the parameters, figures 4.18 and 4.19. It was found that the log plots produced straight lines indicating that the head loss and the material mass follow a power law relationship with time.

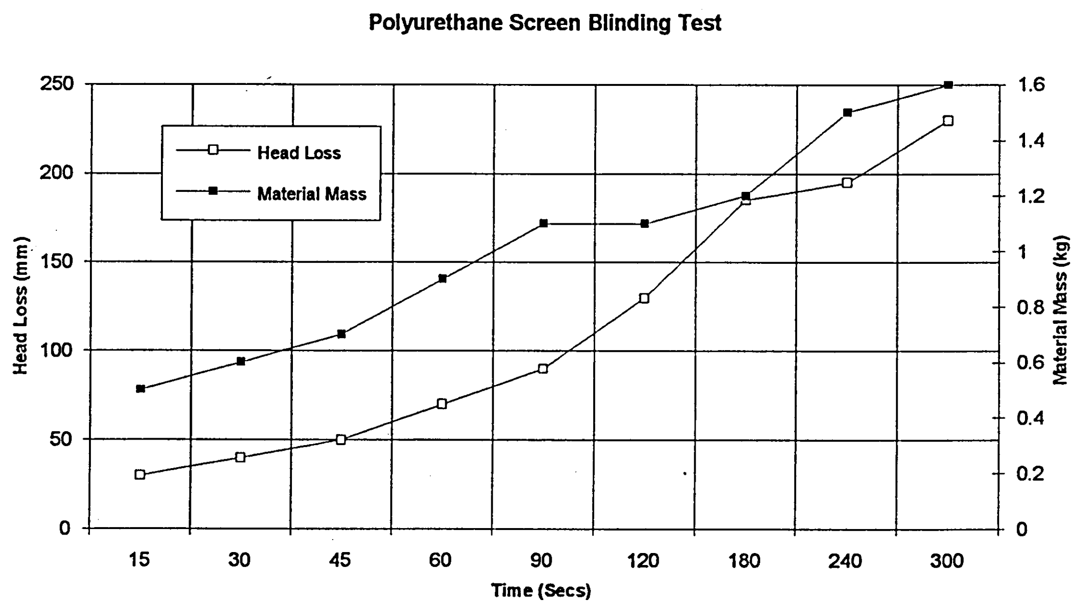


Figure 4.17 Screen Mesh Blinding Test; Head Loss and Material Mass against Time

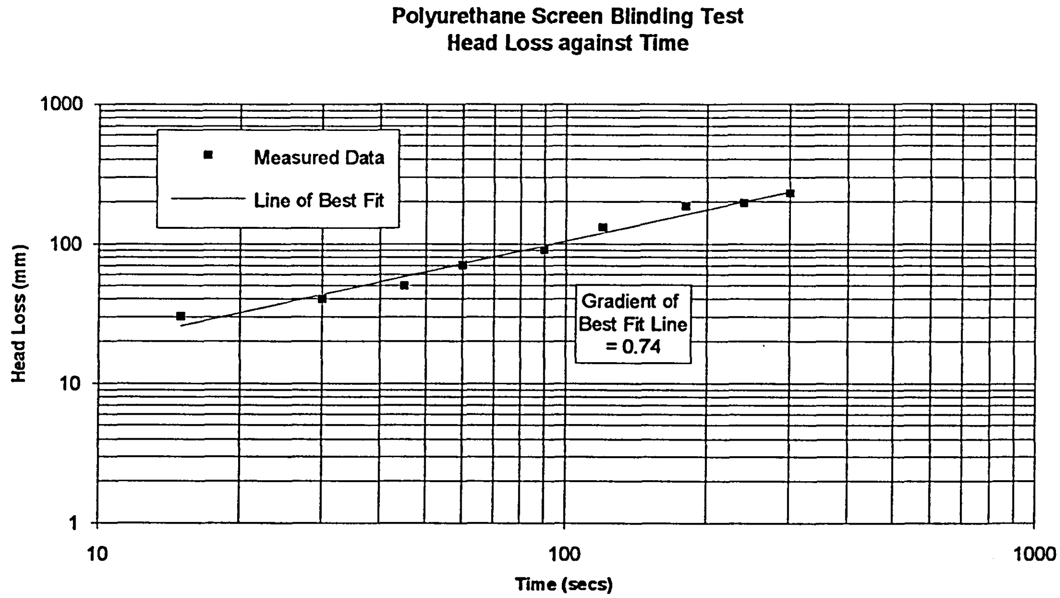


Figure 4.18 Screen Mesh Blinding Tests; Head Loss against Time (Log Plot)

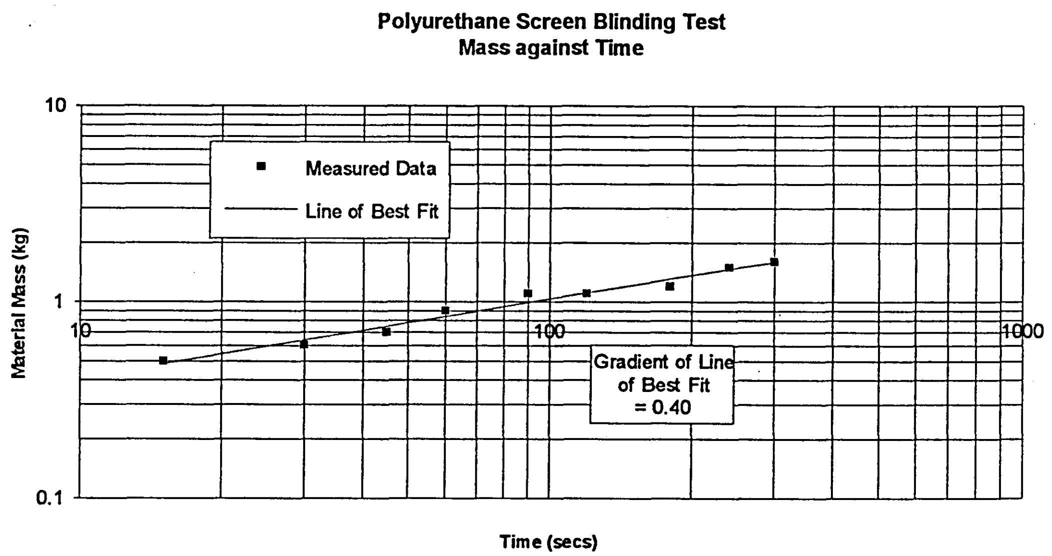


Figure 4.19 Screen Mesh Blinding Tests; Material Mass against Time (Log Plot)

4.3 Laboratory Screen Mesh Tests

The five mesh screens which were tested at the sewage treatment works sites were tested in the laboratory. Testing commenced at the beginning of February 1995 for a period of three weeks, the polyurethane screen mesh being tested in the laboratory at the end of February prior to testing at the sewage treatment works. A full scale channel was constructed to the exact dimensions of the inlet channel at Holbrook sewage treatment works using steel formers and plywood. The three steel screen frames used at Holbrook sewage treatment works were brought back from site, thoroughly cleaned down and used in the laboratory channel to support the test screen meshes and the Copasacs used to retain any material passing through the screens. A 200 mm diameter electromagnetic flow meter (Magmaster) was installed on the inlet pipe together with a manually operated control valve, figure 4.20. A baffle consisting of two coarse (75 mm spacing) screens spaced 300 mm apart, which were offset so that the bar of one was infront of the gap of the other, was fixed immediately in front of the inlet pipe to reduce turbulence in the channel, three sets of guides were installed in the channel in a similar manner to the sewage treatment works to enable the steel frames to be inserted into the channel, figure 4.21. A fourth set of guides were also installed downstream of the screens to hold a fine mesh screen (3 mm) to catch any material which passed through all three screens. A weir could also be manually installed and removed at this point to increase the depth within the channel.

The hydraulics laboratory at Sheffield Hallam University is a new purpose-built laboratory which was only commissioned in January 1995. Consequently, this was the first test work carried out in the new laboratory. In order to carry out comparative tests in the laboratory a mean flowrate of 65 l/s was required. It was found, however, that the header tanks were not capable of maintaining a constant head of water at this flowrate and the tanks were draining below the overflow weir height, exposing the sparge pipes and introducing air into the system. The layout of the ring main for the re-circulating system allowed another pump to be brought on-line to try to maintain the required flowrate. However, the flowrate could still only be maintained for a few minutes. Reducing the flowrate to 50 l/s meant this constant flowrate was maintained

Figure 4.20 Laboratory Flow meter

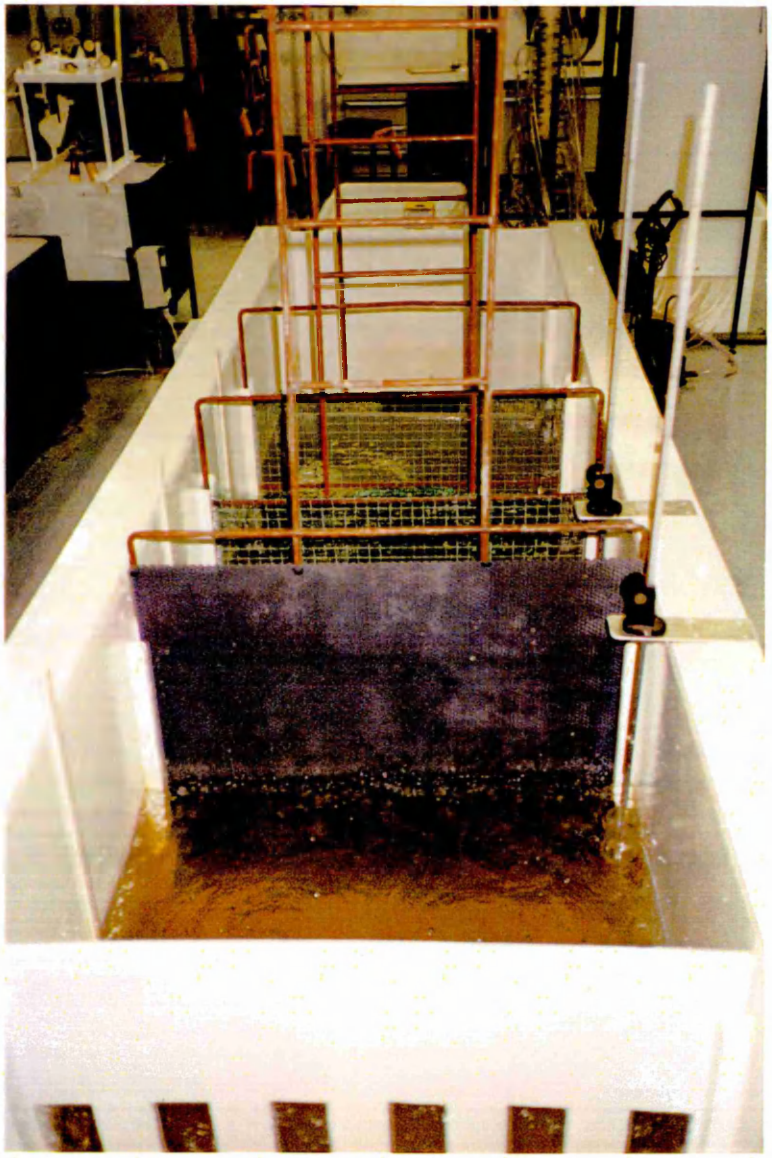


Figure 4.21 Holbrook STW screen mesh frames in position in Laboratory channel

for longer but the header tanks were still draining faster than they were filling and air was still being introduced producing an unsteady flow condition. To rectify the problem the sparge pipes were removed from the header tanks and additional holes were drilled into them to increase the open area of the outlets into the header tanks. This solved the problem but a mean flowrate of 50 l/s had to be used during testing as the system still could not maintain a mean flowrate of 65 l/s.

In order to measure the head loss of the screen mesh and the screening system, a metre rule was fastened to the side of the channel upstream of the test screen mesh, between the test screen mesh and the first Copasac, between the first and second Copasacs and downstream of the second Copasac. During the initial tests, however, it was found that the metre rules were difficult to read and were not providing an accurate head loss measurement. Consequently, two stilling tubes were installed in the channel either side of the test screen mesh. The perspex tubes were held in position using metal clips which allowed the tubes to be moved vertically if necessary. Two metre long pointer gauges were positioned above each tube to enable accurate surface water levels to be determined, figure 4.22.

Actual sanitary products and other products were used to simulate the gross solids found in sewage. The materials chosen for testing were:-

Applicator Tampons

Condoms

Cotton Bud Sticks

Mini Towels

Non-applicator Tampons

Sanitary Towels

Toilet Tissue

The sanitary products were purchased 'off the shelf' from Boots The Chemist and all were Boots own brand and did not contain hygroscopic gel, the cotton bud sticks were

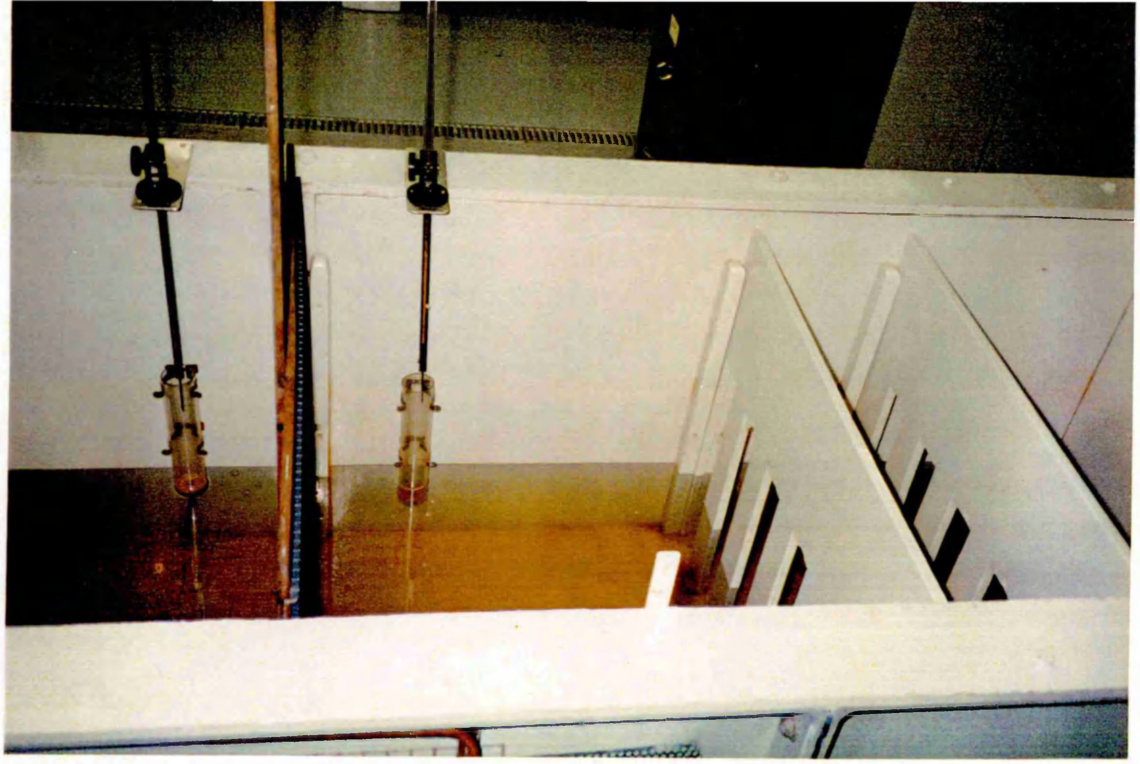


Figure 4.22 Pointer gauges and stilling wells for measuring upstream & downstream depths

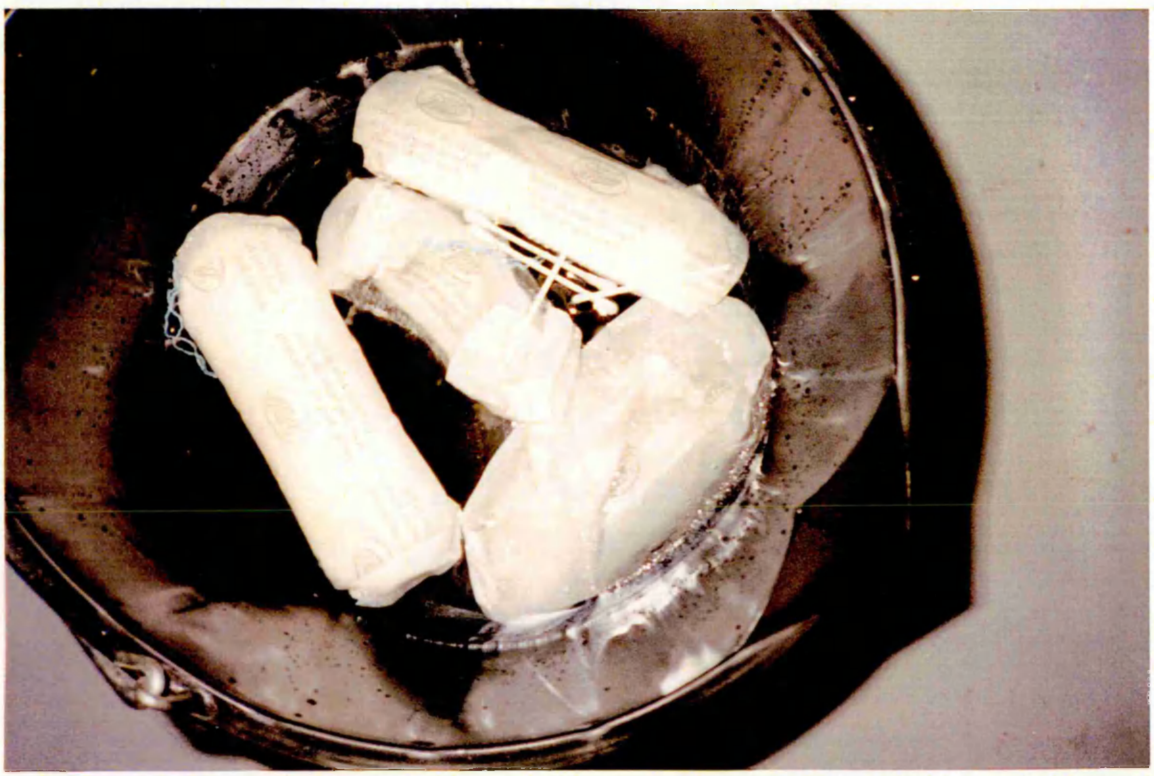


Figure 4.23 Material soaking in a bucket of cold water

also Boots own brand, the condoms used were natural coloured Mates which were spermicidally lubricated and the toilet tissue used was Andrex. Three tests were carried out on each screen:

i) A material observation test

ii) An efficiency test using all the above materials

iii) An efficiency test using only the fine materials

4.3.1 Methodology

The datum readings for each pointer gauge were established by blocking the outlet orifice of the laboratory channel and allowing the water to back-up, the flow was then switched off and the depth of water in the channel recorded together with the surface water level readings from the upstream and downstream gauges. Each test was carried out at a flow rate of 50 l/s, the three screen frames were inserted into the channel prior to the flow of water in the channel being turned on. The weir downstream of the screen was fitted for each test to give a depth of flow in the channel of approximately 500 mm.

The observation and overall efficiency tests were carried out simultaneously using the following materials:

1 Condom

2 Cotton Bud Sticks with cotton

2 Cotton Bud Sticks with out cotton

1 Mini Towel (Whole)

1 Mini Towel Inner

1 Mini Towel Shell

1 Sanitary Towel (Whole)

1 Sanitary Towel Inner

1 Sanitary Towel Shell

1 Tampon - Applicator

2 Tampons - Non- Applicator

Toilet Tissue - 10 sheets

Toilet Tissue - 5 sheets

All the materials except the toilet tissue were soaked in a bucket of cold water for 5 minutes, they were then removed, drained and weighed. The sanitary towel inners and the 10 sheets of toilet tissue were agitated in a mechanical shaker in 500 ml of cold water for 5 minutes. Each material was then introduced separately into the flow upstream of the test screen mesh between the baffle arrangement and was observed approaching and being presented to the screen. Once all the materials had been introduced the flow was left for 5 minutes before being turned off and the test screen mesh along with the Copasac frames were removed from the channel. The material retained by the screen was sorted and drained and then weighed on a laboratory top pan balance. Any material remaining on the test screen mesh was removed using a paint scraper, drained and weighed. The Copasacs were removed from their frames and weighed to determine the mass of material passing through the test screen mesh, the weight of the Copasac being deducted to obtain the net weight of the material collected. The head loss across the screen was recorded for each test before the introduction of the materials when the screen was clean and after the material introduction when the screen had partially blinded.

All the five screen meshes tested retained whole mini towels and sanitary towels, mini towel shells and sanitary towel shells, condoms and cotton bud sticks with cotton all of the time giving these particular materials a 100 % efficiency of retention. It was decided, therefore, to concentrate the efficiency tests on those materials which have an efficiency of retention of less than 100 %. Each efficiency test consisted of:

1 Mini Towel Inner

1 Sanitary Towel Inner

1 Tampon - Applicator

2 Tampons - Non-Applicator

Toilet Tissue - 10 sheets

Toilet Tissue - 5 sheets

Each material except the toilet tissue was soaked in a bucket of cold water for 5 minutes before being removed, drained and weighed, all the above materials except 5 sheets of toilet tissue were then agitated in a mechanical agitator for 5 minutes in 500 ml of cold water before being introduced into the flow; figures 4.23 and 4.24. The 5 sheets of toilet tissue were introduced into the flow by hand.

Each test lasted 5 minutes after which time the flow was turned off, figure 4.25 the channel allowed to drain and the steel frames removed from the channel and laid across the top of it so the material retained by the screen mesh and the Copasacs could be removed; figures 4.26 to 4.28. The material was removed from the test screen using a paint scraper, drained and weighed on a laboratory top pan balance the Copasacs were removed from the other two screen frames, drained and weighed on a laboratory top pan balance, the weight of a Copasac being deducted from the total weight to obtain the net material weight. By knowing the weight of material introduced and the weight of material retained by the screening system, the weight of material lost could be determined and the retention efficiency of the screening system determined to check the methodology used at the sewage treatment works was accurate.

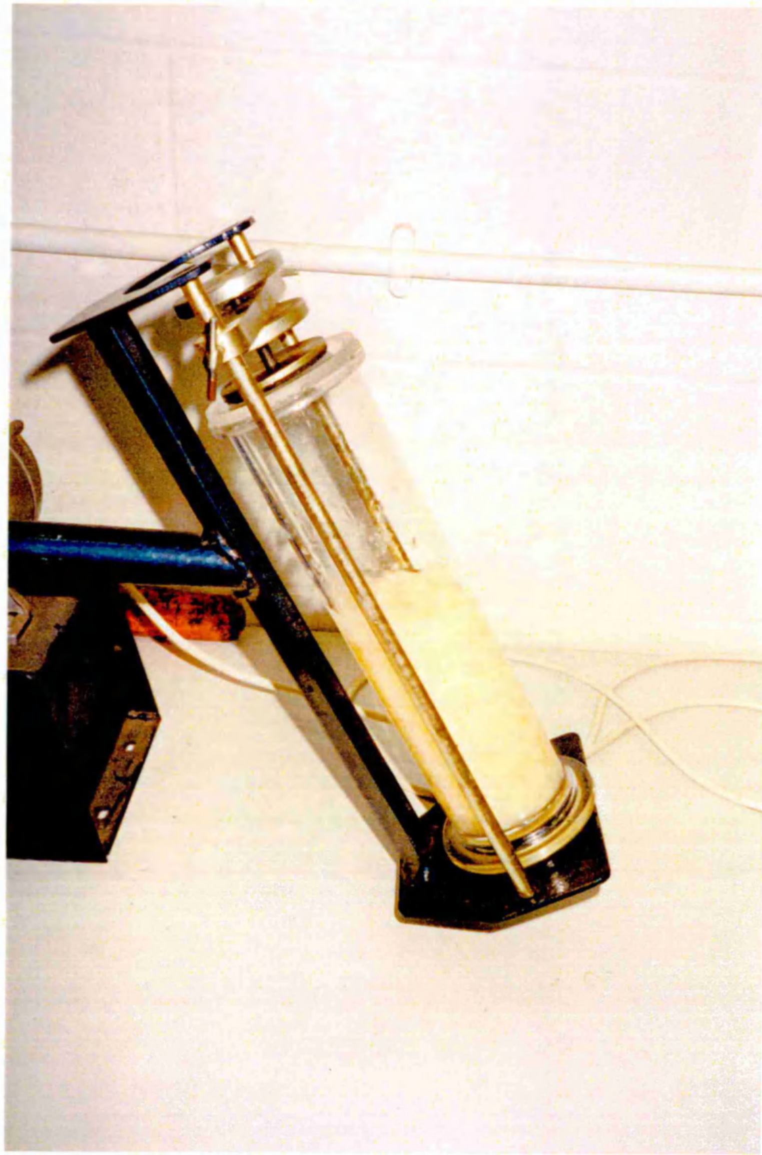


Figure 4.24 Fine material being agitated in mechanical agitator

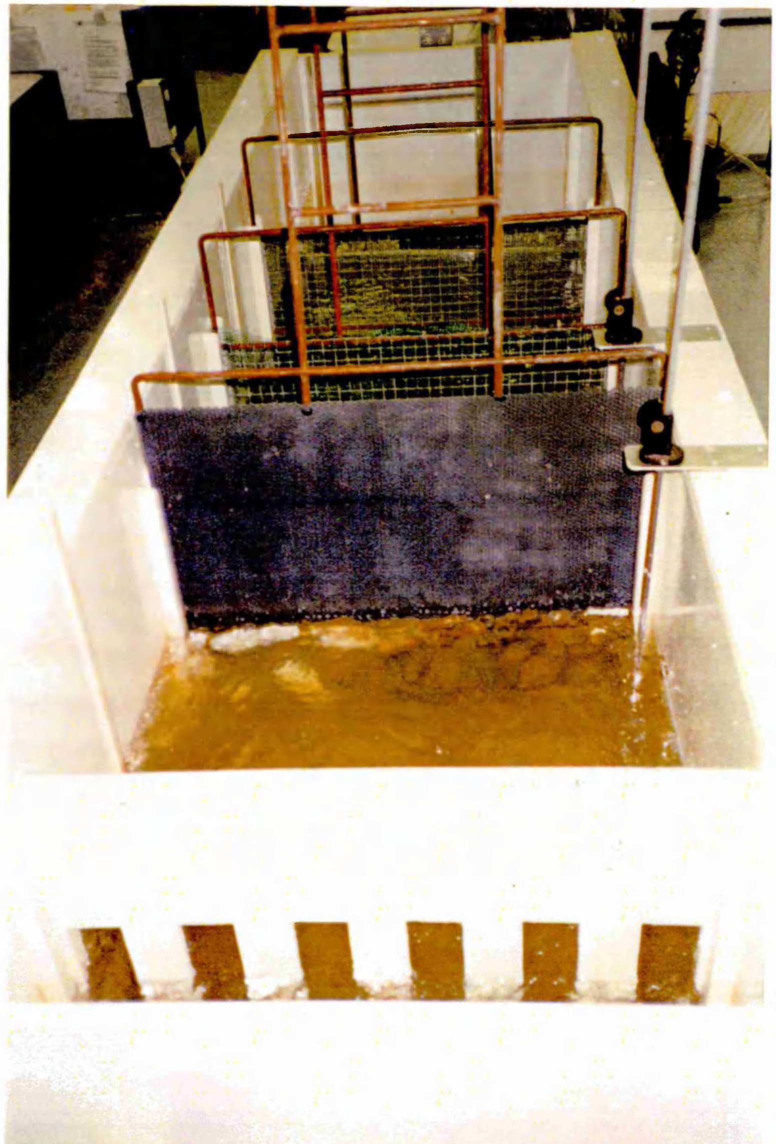


Figure 4.25 Laboratory channel during test after material introduction

Figure 4.26 Test screen mesh after test before being cleaned

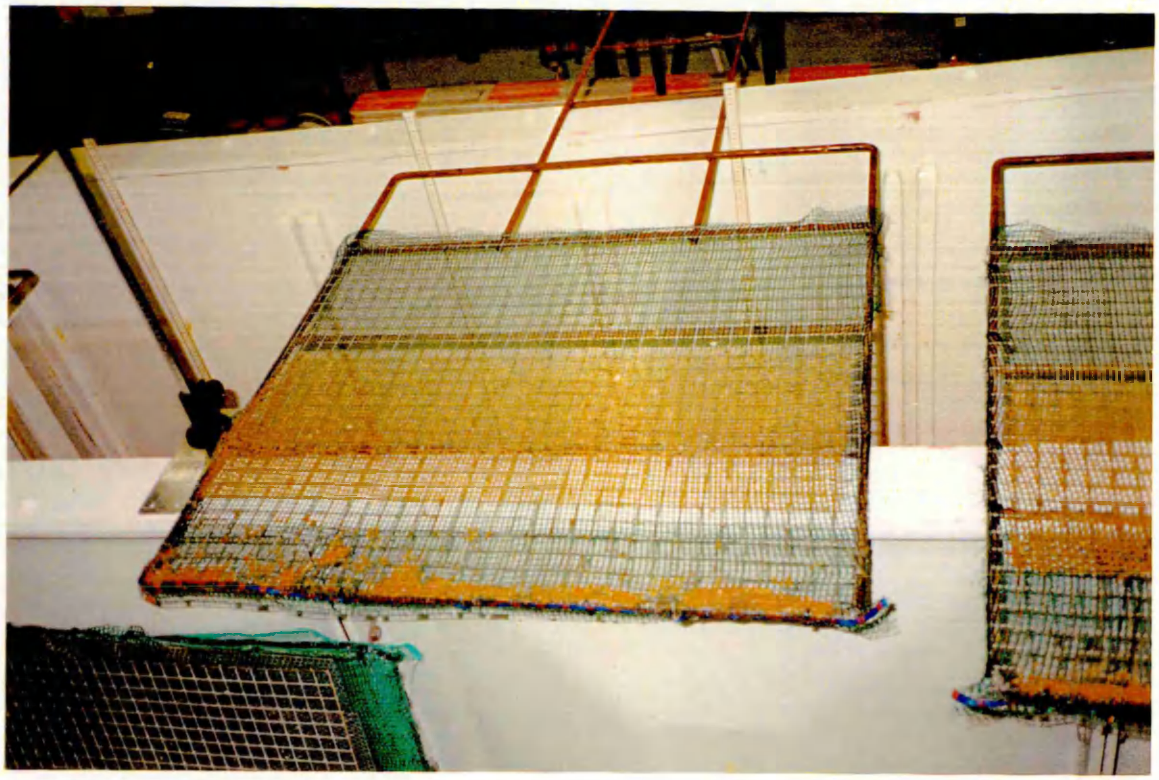


Figure 4.27 First Copasac capture mesh after test

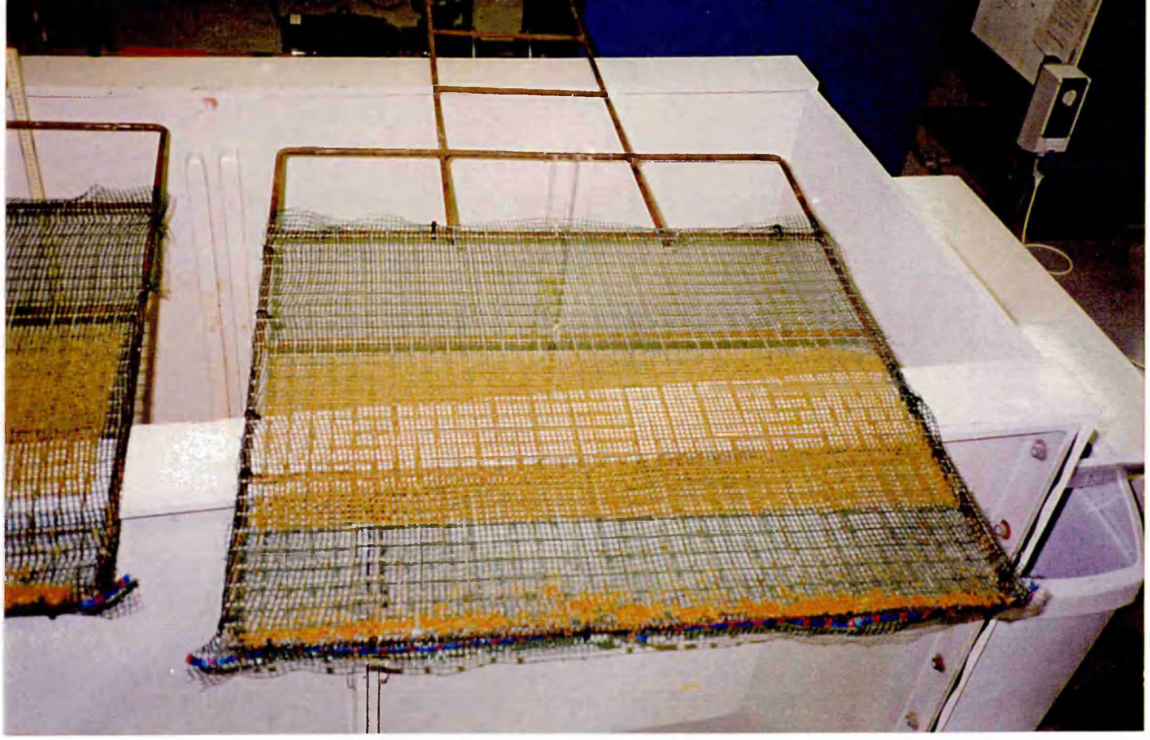


Figure 4.28 Second Copasac capture mesh after test

4.3.2 Results of laboratory screen mesh tests

The mean screen retention efficiencies for the five screen meshes are presented in table 4.10. Tables 4.11 and 4.12 show the mean screen head losses for the overall efficiency tests and the fine material efficiency tests. The mean composition of gross solids used for each overall efficiency test and for each fine material efficiency test are given in table 4.13.

Table 4.10 Screen Retention Efficiencies

Screen Material	Overall Efficiency (%)	Standard Deviation (± %)	Fine Material (%)	Standard Deviation (± %)
6.0 mm Copasac	56	1.17	42	2.79
6.4 mm Round Perforated	55	0.55	28	3.49
6.0 mm Square Staggered Perforated	49	5.05	29	2.70
6.0 mm Square Perforated	64	11.80	27	3.29
6.0 mm Round Polyurethane	53	2.65	27	2.80

Table 4.11 Mean Screen Head Loss (Overall)

Screen Material	Clean (mm)	Standard Deviation (± mm)	Partially Blinded (mm)	Standard Deviation (± mm)
6.0 mm Copasac	3	2	18	1.73
6.4 mm Round Perforated	3	0	8	1.73
6.0 mm Square Staggered Perforated	0	0.58	12	1.53
6.0 mm Square Perforated	3	2.08	8	3.51
6.0 mm Round Polyurethane	2	0.58	9	0.58

Table 4.12 Mean Screen Head Loss (Fine Material)

Screen Material	Clean (mm)	Standard Deviation (± mm)	Partially Blinded (mm)	Standard Deviation (± mm)
6.0 mm Copasac	1	1.30	4	1.05
6.4 mm Round Perforated	3	0.63	5	1.83
6.0 mm Square Staggered Perforated	1	0.74	4	0.87
6.0 mm Square Perforated	1	0.82	4	2.25
6.0 mm Round Polyurethane	2	1.03	4	1.83

No obvious difference in the behaviour of material approaching and being retained on the screen was observed between the five different test screen meshes.

Applicator Tampons; These tampons are suspended within the flow and are carried along within the body of the fluid. The tampons are presented to the screen mesh end on, they are then turned by the flow so the largest surface area is in contact with the screen mesh. Some shredding of the fibres of the tampon does occur but the central string to which the cotton fibres are attached keeps most of them intact.

Condoms; These behave in a similar way to sanitary and mini towel shells. Whether they float or are pulled down into the body of the fluid depends on the amount of water inside them and whether or not they have been tied. If they are empty they float, if water gets inside them they are pulled into the flow and quickly forced against the screen mesh. The amount of air inside them dictates whether they float or are pulled into the flow when they have been tied. The observation test would have been easier if the condoms had not been natural coloured because once they had been pulled into the body of the fluid they became almost invisible in the water and once or twice were not seen again until they had already been retained by the screen mesh.

Fluorescent coloured condoms would have been more easily detected for the observation tests.

Cotton Bud Sticks with cotton; Cotton bud sticks float and tend to be caught up in eddies around the baffle. When they float towards the screen mesh they are parallel to the screen mesh but as they approach the screen mesh the flow turns the sticks perpendicular to the screen mesh and the sticks try to pass through the perforations, however, the cotton on the end prevents this. In one case a cotton end did pass through a hole in a screen mesh but the cotton on the other end of the stick prevented passage through.

Cotton Bud Sticks without cotton; These behave exactly the same as cotton bud sticks with cotton, however, some of the sticks do pass through the holes. Whether they do or not is purely random. Cotton bud sticks without cotton passed through every screen mesh except the Copasac screen, it was also found difficult to try and manually push a cotton bud stick through a Copasac screen.

Non-Applicator Tampons; As with applicator tampons, non-applicator tampons are suspended within the flow, however, their construction is very different to applicator tampons, the cotton being wrapped around the string of the tampon. Most non-applicator tampons unravel themselves before they reach the screen mesh becoming a fibrous mass over the screen mesh face.

Sanitary and Mini Towel Shells; Most of these float, occasionally one will be pulled down into the body of the fluid and carried along by the flow. Most of those that float are not really presented to the screen mesh they just float around in front of it, sometimes the flow pushes them onto the screen mesh and they become forced onto the screen mesh, their largest surface area being in contact with the mesh face.

Sanitary Towels (Whole) and Mini Towels (Whole); The behaviour of these particular products depends on their water content. After an initial wetting the products float. They pass through the baffle end on and are then turned by the flow upstream of the screen so they are parallel to the screen. As they approach the screen mesh they are turned again and become perpendicular to the screen mesh, as they meet the screen forwards movement is prevented and the flow turns them onto the screen mesh on edge, the direction depends upon the inclination of the product to the screen mesh. Once parallel to the screen the flow forces the towels downwards against the face of the screen mesh so the largest surface area of the towel is in contact with the screen mesh.

Tampon Applicator (Cardboard); These cardboard tubes are made up of parallelograms which separate when soaked in water. When introduced into the flow these parallelograms of cardboard become submerged in the flow and are laid or pressed onto the screen mesh so their largest surface area is in contact with the mesh face.

Toilet Tissue; When dry sheets of toilet tissue enter the flow they quickly absorb water and become saturated, they are then entrained within the flow and pulled into the body of the fluid before being laid on the screen mesh face in complete sheets. The flow then begins to break the tissue down forcing some of it through the mesh, the longer the paper remains on the screen mesh, the more paper is passed through. Wet clumps of toilet tissue introduced into the flow have already lost much of their strength and are quickly broken down into small pieces of fine paper suspended within the body of the fluid, a high percentage of this material passes straight through the screen mesh, to be retained by the Copasacs further down the channel.

Table 4.13 Mean Composition of Gross Solids used during each test

Material	Overall Efficiency Test (%)	Fine Material Test (%)
Condom	1.3	
Cotton Bud Stick with Cotton	0.5	
Cotton Bud Stick with Cotton	0.5	
Cotton Bud Stick without Cotton	0.3	
Cotton Bud Stick without Cotton	0.3	
Mini Towel (Whole)	11.7	
Mini Towel Inner	9.7	16.0
Mini Towel Shell	1.8	
Sanitary Towel (Whole)	18.8	
Sanitary Towel Inner	15.2	27.0
Sanitary Towel Shell	2.0	
Tampon - Applicator	5.7	8.9
Tampon Applicator	2.2	
Tampon - Non-applicator	5.7	8.4
Tampon - Non-applicator	4.4	8.5
Toilet Tissue - 10 sheets	13.2	20.5
Toilet Tissue - 5 sheets	6.7	10.7
Total	100	100

4.3.3 Discussion of laboratory screen mesh tests

Care was taken when choosing materials for testing in the laboratory to try to reproduce the characteristics of the gross solids collected at the sewage treatment works. It was not possible to generate the head losses measured on site in the laboratory, because of the amount of fine material required to reproduce the partial screen blinding experienced in the field. It was not practical in a recirculating laboratory system to introduce such a volume of fine material. Consequently the head losses measured in the laboratory were much smaller than those measured in the field tables 4.11 and 4.12.

The material composition used for each observation and overall efficiency test also differed from the composition found at the sewage treatment works, the percentage of fine paper being half the actual percentage in the field and the percentages of condoms, cotton bud sticks, sanitary towels and tampons being 4 to 5 times greater, table 4.13. However, with the fine material efficiency tests, whilst the amount of material introduced is much less than the sewage treatment works, the proportions retained by the three screens should be similar to those found at the sewage treatment works.

There was no obvious explanation for the large differences in the overall efficiency standard deviations for the five screens. One possible explanation is the variability of the actual material. In theory the weight of the material introduced into the flow should be the same for each test, however, this was clearly not the case. This was confirmed by the material observation tests. If the materials were exactly the same they should behave in a similar manner but this was not always the case and occasionally a 'rogue' material would behave quite differently. For example, most non-applicator tampons unravel in the flow and disintegrate into a fibrous, fine material, a percentage of which will pass through the screen mesh, but occasionally one will remain whole and intact and all of the material will be retained by the screen mesh.

The 6.0 mm square perforated steel screen mesh was found to have the highest retention efficiency in the laboratory and the 6.0 mm square staggered perforated steel screen mesh the lowest retention efficiency. However, the 6.0 mm plastic mesh

Copasac had the highest fine material retention efficiency, this efficiency being 1.5 times higher than the other four screen meshes, table 4.10.

4.4 Laboratory Gross Solids Settling Velocity Tests

4.4.1 Methodology

The settling and rise characteristics of the gross solids which cause aesthetic pollution were investigated by carrying out a series of settling velocity tests on a variety of materials commonly found in sewage, e.g. sanitary towels. This was done to try to provide a clearer picture of the behaviour of gross solids within the sewerage system and how they may be presented to the CSO screens.

The initial settling velocity tests were carried out in a 100 mm diameter, perspex tube approximately 1.5 m long which was filled with water. The material under test was placed inside the tube of water and the end was sealed using a circular piece of perspex which fitted over four threaded bars and was held in position using four nuts tightened with a spanner, figure 4.29. The material was then timed settling over a metre length marked in the middle of the tube. The tube was then turned manually and the test repeated. Any materials which were found to have a negative settling velocity (i.e. floated rather than sinking) could also be timed over the metre by turning the column over to start the test. Each material was tested in the perspex tube dry, after being soaked overnight and after being mechanically agitated in 500 ml of water. The materials used for the tests were:

Applicator Tampons

Condoms

Panty Liners

Regular Sanitary Towels

Superslim Sanitary Towels

Tampon Applicators (cardboard)

Figure 4.29 100 mm diameter perspex column

All the sanitary products tested were Boots own brand and the condoms were Durex. A regular sanitary towel is made up of several components, a fibre/film of gauze covers the whole of the outside of the product, the base of the towel has a plastic waterproof backing inside the gauze, above the waterproof backing is another layer of gauze, and a cotton wool/fibre pad is sandwiched between the middle layer of gauze and the outer one. Self-adhesive tapes are provided on the base of the towel and these have a plastic peel-off strip covering them. It was found that the waterproof plastic element of the sanitary towel was very strong and this particular material could not be pulled apart easily, indicating that degradation of the plastic within the sewerage system was unlikely. Superslim sanitary towels are fabricated in a similar manner except they have less cotton fibre padding. In order to provide the same amount of protection as a regular sanitary towel, the missing cotton padding is replaced with a hygroscopic gel which swells as it absorbs moisture, a similar sort of gel is often found inside disposable nappies. Panty liners are basically thinner, smaller versions of the regular sanitary towel which have the same components only much less cotton fibre inner, they are harder to split open than the other two types examined. Applicator tampons consist of an absorbent pad of cotton fibre which is attached to a central cord, many products on the market now have a sewn-in cord which reduces the breakdown of the tampon into a fibrous mass and some have a fine gauze overwrap which minimises fibre shredding. The tampons used for these tests were found to have a sewn-in cord but on agitation produced a lot of fibre shredding.

The perspex tube was found to be inappropriate for the test being carried out. The narrow diameter of the tube prevented the products from moving freely up and down within it, and it was impossible to seal the end of the tube without incorporating some air into the tube which influenced the speed at which material travelled. Some of the materials were found to either travel rapidly up the tube on a pocket of air or be slowed down as a bubble of air tried to pass them. The materials also frequently came into contact with the sides of the tube and the friction between each material and the inside of the tube interfered with the results.

The tests were repeated in a 500 mm perspex cylinder which enabled the materials to move freely around within the body of the water contained by the cylinder, figure 4.30. The cylinder was approximately 2 m high and stood on a square wooden platform which had a 500 mm circular section routed out of the middle. The cylinder sat inside the circular section and was sealed with silicone sealant around the base to make it watertight. Each material was placed in the cylinder by hand, care was taken not to influence the behaviour of the material, figure 4.31. Those materials which had a negative settling velocity were released at the bottom of the column using a mechanical arm. The materials were timed over a central metre length marked out on the column which gave each material time to establish a steady velocity. Only two different types of material were tested in this column and these were chosen because they formed a higher percentage of the gross solids sample than any of the other materials, except tissue paper. This was not tested because the breakdown of this material into a fine paper held in suspension in the water meant the column would have had to be drained and cleaned after each test, making testing impractical.

The two materials tested were Boots regular sanitary towels and Boots panty liners. Fifty of each material were tested and each one was labelled numerically from 1 to 50 using a marker pen so they could be identified for each test. Both products were tested dry. They were then soaked in a bucket of water for 24 hours and tested again. Following a further soaking for 24 hours each towel and liner was tested again. The towels and liners were then split and their cotton inners removed, the remaining plastic shell was then tested.

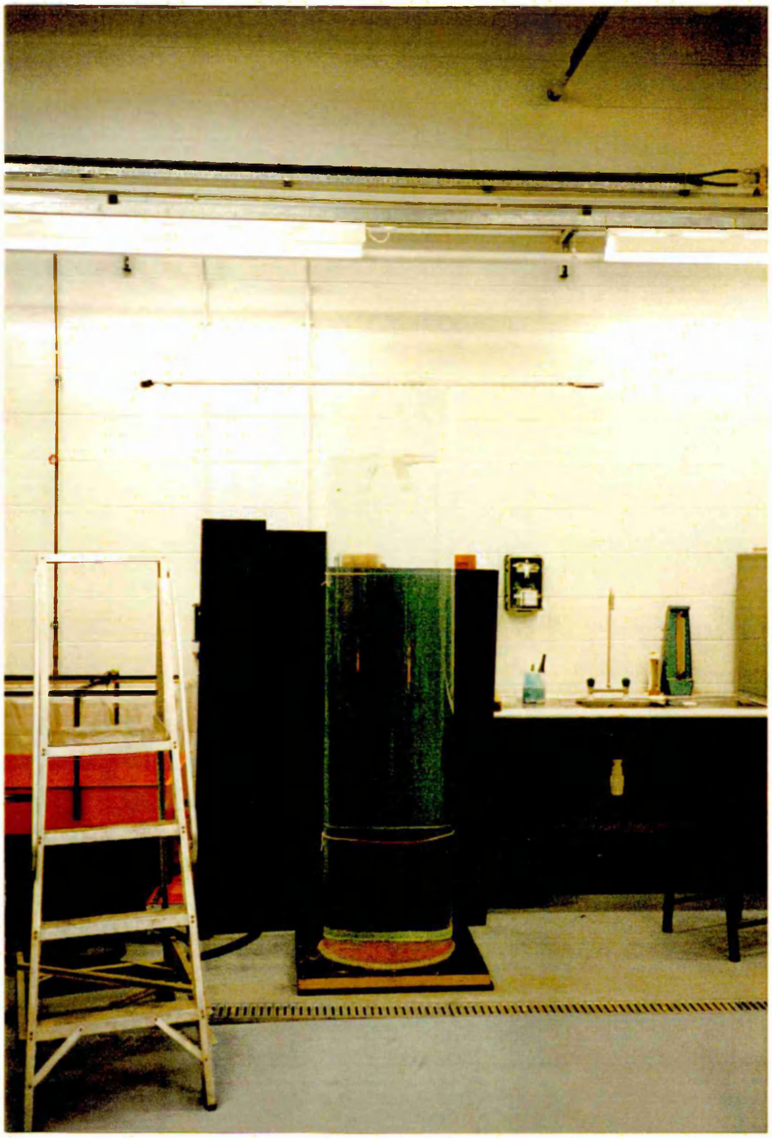


Figure 4.30 500 mm diameter perspex column

Figure 4.31 Material rising in 500 mm diameter column

4.4.2 Results of settling velocity tests

Table 4.14 shows the results of the settling velocity tests. The results for each individual towel are presented in tables 4.15 and tables 4.16, the time for each towel to travel one metre are given together with the corresponding terminal velocity. Figures 4.32 and 4.33 illustrate the change in velocity of each towel with each test and figures 4.34 to 4.41 show the deviations from the mean for each towel.

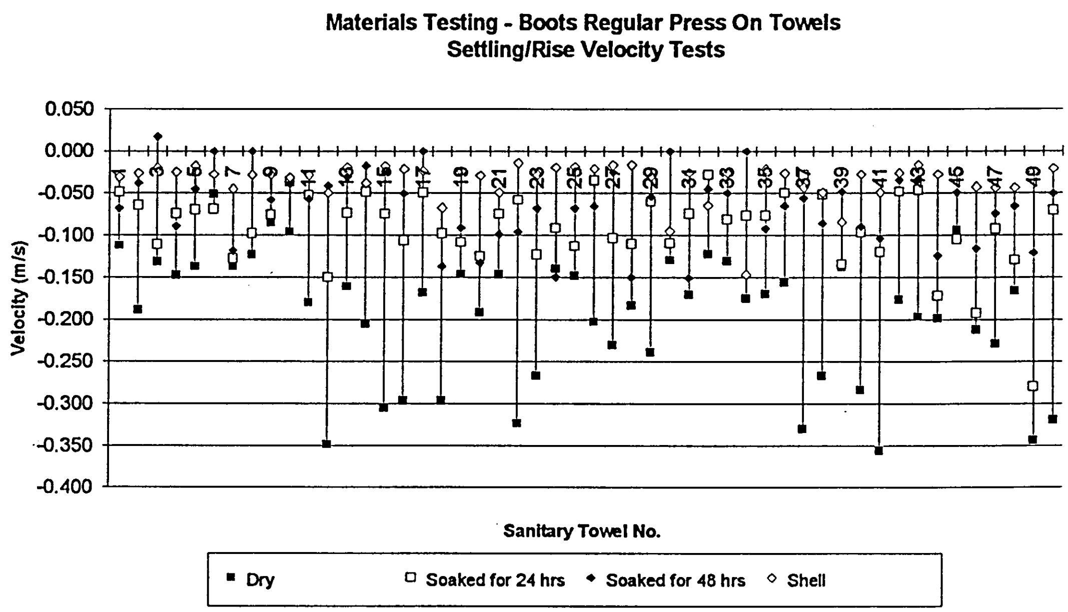


Figure 4.32 Velocity change of each press-on towel with each test

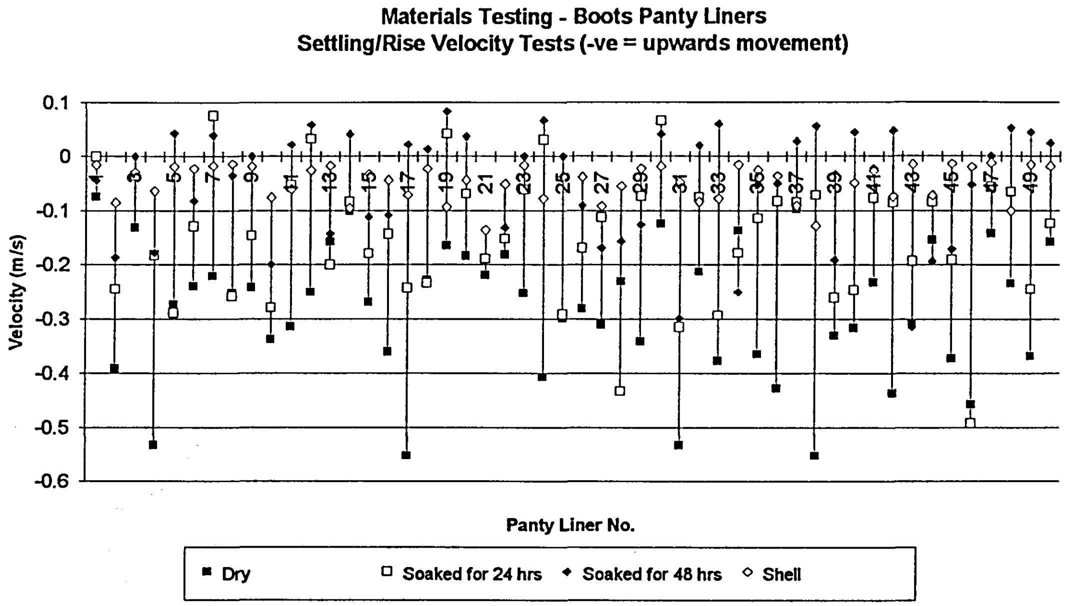


Figure 4.33 Velocity change of each panty liner with each test

Table 4.14 Settling Velocities of Materials tested in 500 mm Column

	Mean Terminal Velocity (m/s)	Standard Deviation (± m/s)
Regular Sanitary Towel		
Dry	-0.195	0.076
Soaked for 24 hrs	-0.090	0.045
Soaked for 48 hrs	-0.066	0.042
Plastic Shell	-0.035	0.023
Panty Liner		
Dry	-0.282	0.121
Soaked for 24 hrs	-0.147	0.118
Soaked for 48 hrs	-0.053	0.104
Plastic Shell	-0.047	0.032

4.4.3 Discussion on settling velocity tests

The variability of the gross solids found in sewage has been demonstrated with these tests. The products used for each test were identical and all were tested in exactly the same way under the same conditions. These tests also reinforce the differences in material behaviour of the same product observed in the laboratory during the screen mesh efficiency tests. The variation in the terminal velocities of these materials under varying conditions together with the variation in the different types of products available make standardisation of values very difficult (table 4.14). This means the behaviour of these materials is also difficult to predict.

4.5 Comparison between Field Results and Laboratory Results

The mean screen retention efficiencies found at Holbrook STW, Long Lane STW and in the Laboratory are compared in table 4.15 for all five screen meshes. Similar comparisons are also made in table 4.16 for the mean flow rate through the screen meshes during the tests and the mean screen head loss for each screen mesh is examined and compared in table 4.17. Table 4.18 clearly shows the differences in the composition of each material sample collected at the three testing locations.

Table 4.15 Comparison of Mean Screen Retention Efficiencies

Screen Material	Holbrook STW (%)	Long Lane STW (%)	Laboratory Testing (%)
6.0 mm Plastic Mesh Copasac	49	64	56
6.4 mm Round Perforated Steel	58	64	55
6.0 mm Sq. Staggered Perforated Steel	49	55	49
6.0 mm Square Perforated Steel	52	58	64
6.0 mm Round Perforated Polyurethane	48	59	53

Table 4.16 Comparison of Mean Flow Rate through Screens

Screen Material	Holbrook STW (l/s)	Long Lane STW (l/s)	Laboratory Testing (l/s)
6.0 mm Plastic Mesh Copasac	69	75	50
6.4 mm Round Perforated Steel	76	80	50
6.0 mm Sq. Staggered Perforated Steel	53	89	50
6.0 mm Square Perforated Steel	61	82	50
6.0 mm Round Perforated Polyurethane	115	102	50

Table 4.17 Comparison of Mean Screen Head Loss

Screen Material	Holbrook STW (mm)	Long Lane STW (mm)	Laboratory Testing (mm)
6.0 mm Plastic Mesh Copasac	113	195	18
6.4 mm Round Perforated Steel	49	128	8
6.0 mm Sq. Staggered Perforated Steel	82	106	12
6.0 mm Square Perforated Steel	106	294	8
6.0 mm Round Perforated Polyurethane	60	113	9

Table 4.18 Comparison of Mean Material Composition

Material	Holbrook STW (%)	Long Lane STW (%)	Laboratory Testing (%)
Condoms	0.0	0.0	1.3
Cotton Bud Sticks	0.3	0.3	1.6
Fine Paper etc.	96.9	85.1	47.0
Sanitary Towels	2.5	10.1	34.3
Tampons	0.3	4.5	15.8

4.6 Concluding Discussion

The laboratory tests carried out on the five screen meshes have produced overall screen retention efficiencies which are comparable with those found in the field, the lowest and highest screen retention efficiencies being almost the same as the sewage treatment works, i.e. 49% and 64% respectively. However, none of the screens tested were found to have the same or similar retention efficiencies at the three locations, table 4.15.

From the tests carried out it would appear that the laboratory testing can predict the screen retention efficiencies likely to be found in the field. However, the laboratory testing was carried out after the field tests, and the experience gained from the field work was used to simulate the material collected at the sewage treatment works. Without this knowledge it is unlikely that the laboratory tests would have represented the site situation. It is clear from the results of the settling velocity tests carried out on the two different sanitary products that simulation of these products is very difficult due to the variability and nature of the material.

It is also clear from the results that the laboratory tests cannot predict the screen head losses likely to be encountered in the site environment. So the laboratory tests need to be carried out with prior knowledge of the field situation and a different laboratory test devised to cover the range of head losses found in the field.

The tests provide comprehensive evidence of the potential performance of screen meshes. In practice the overall efficiency of screens are affected by other factors such as the method of cleaning the screen mesh during operation. Based on the above results it is unlikely that an overall efficiency of greater than 60% can be achieved. It should be remembered, however, that the efficiency of retaining different materials is very varied, with the retention of large solids such as sanitary towel shells being far greater, and the retention of fine tissue much less.

These tests have also shown that the retention efficiency of 6 mm plastic mesh Copasacs is at best 64% and at worst 49%, indicating that the assumption made during the bar screen monitoring in Chapter 3 that the Copasac collection method caught 100% of the gross solids passing through the screens is flawed. The actual mean retention efficiency of the Copasacs is 56%, thus the screen retention efficiencies given in Chapter 3 should be factored by 0.56 to allow for the retention efficiency of the plastic mesh Copasacs used to measure their performance. This then gives a mean screen retention efficiency of 10% for the 25 mm STW D-screen, 18.5% for the Extended stilling pond CSO 15 mm D-screen, 20% for the Sharpe and Kirkbride stilling pond CSO 15 mm D-screen and 29% for the 6 mm STW inclined bar screen.

Settling/Rise Velocity Tests

500 mm Diameter Column

Regular Press-on Towels

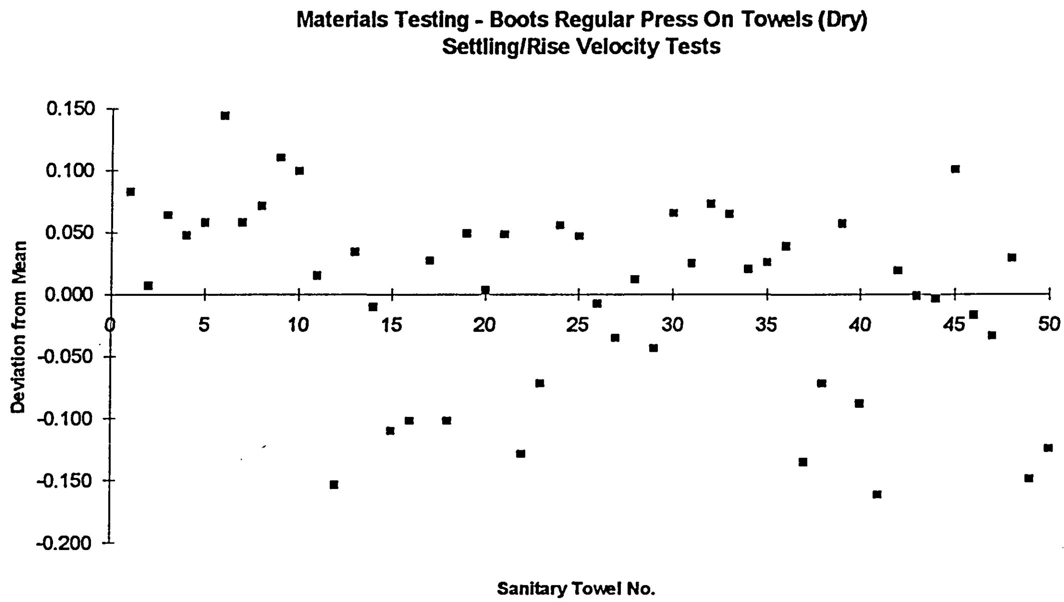


Figure 4.34

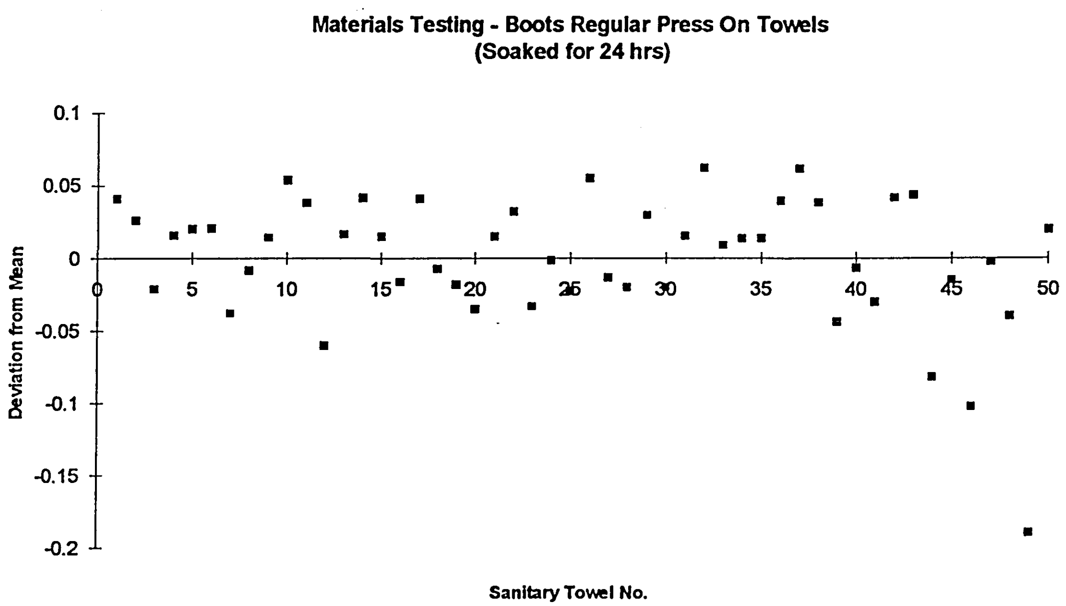


Figure 4.35

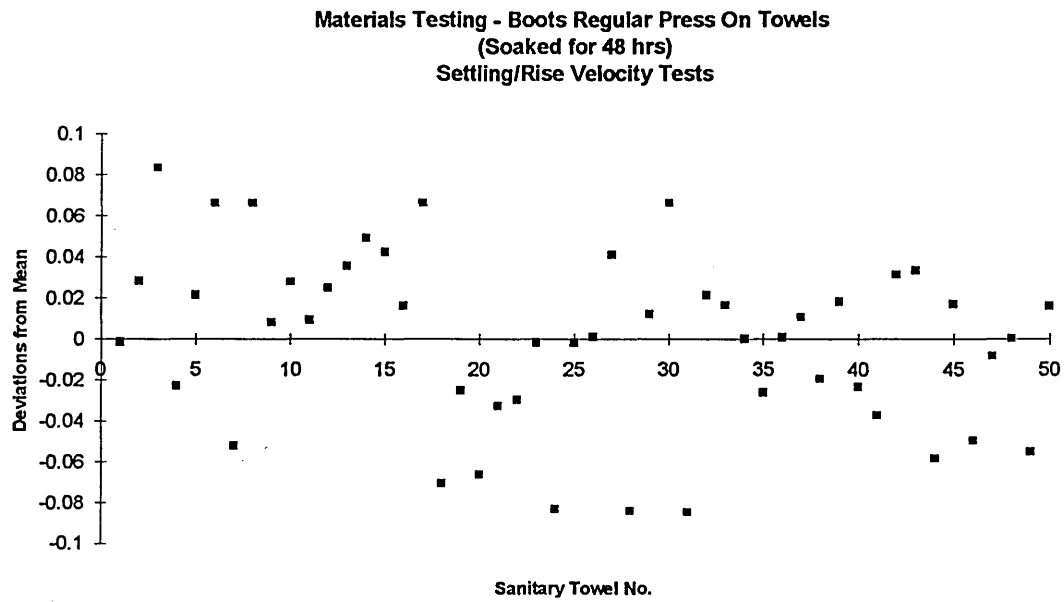


Figure 4.36

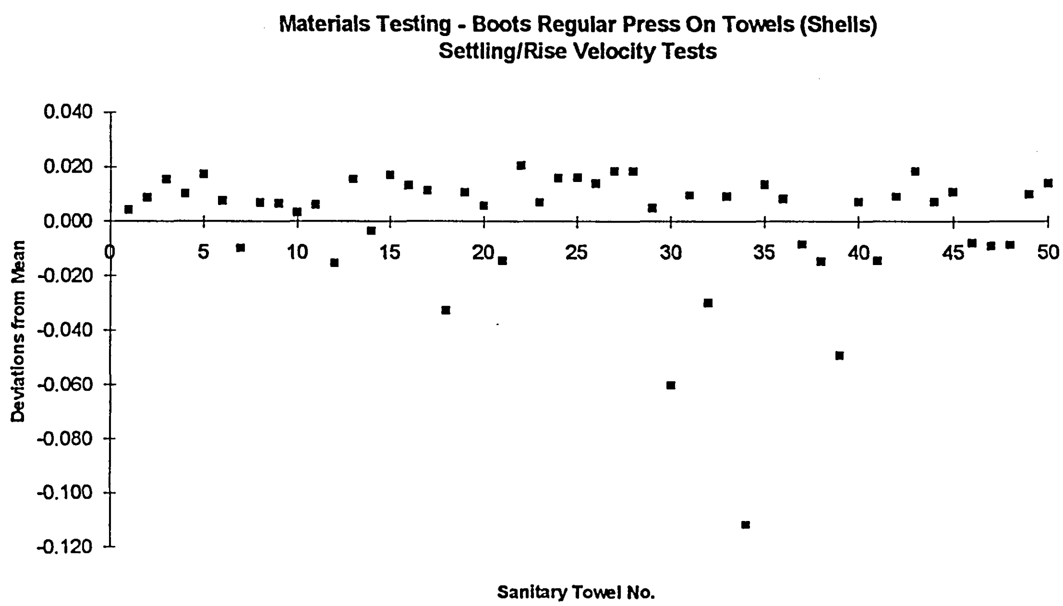


Figure 4.37

Settling/Rise Velocity Tests

500 mm Diameter Column

Panty Liners

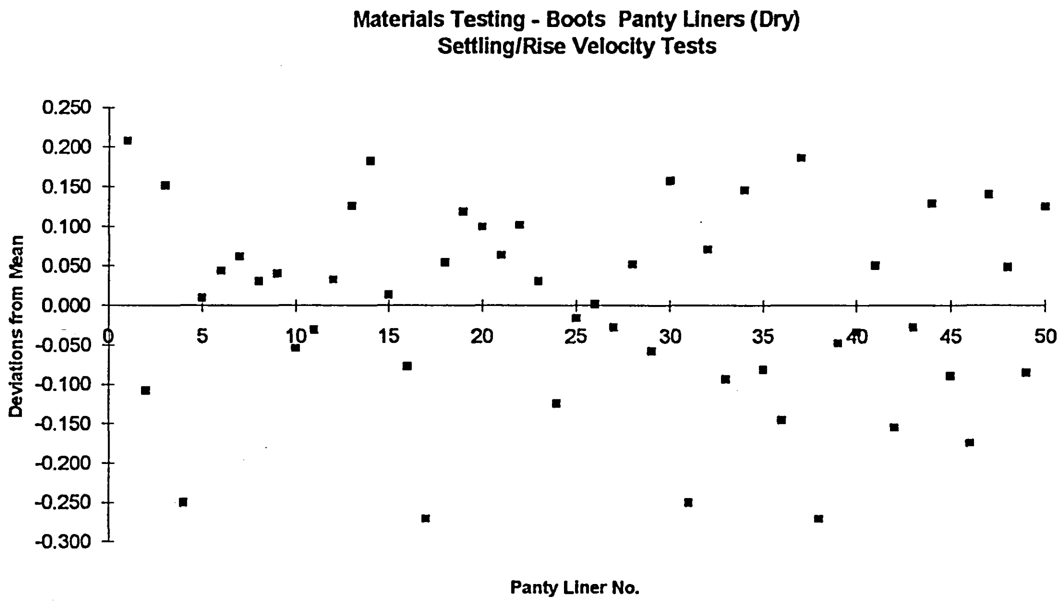


Figure 4.38

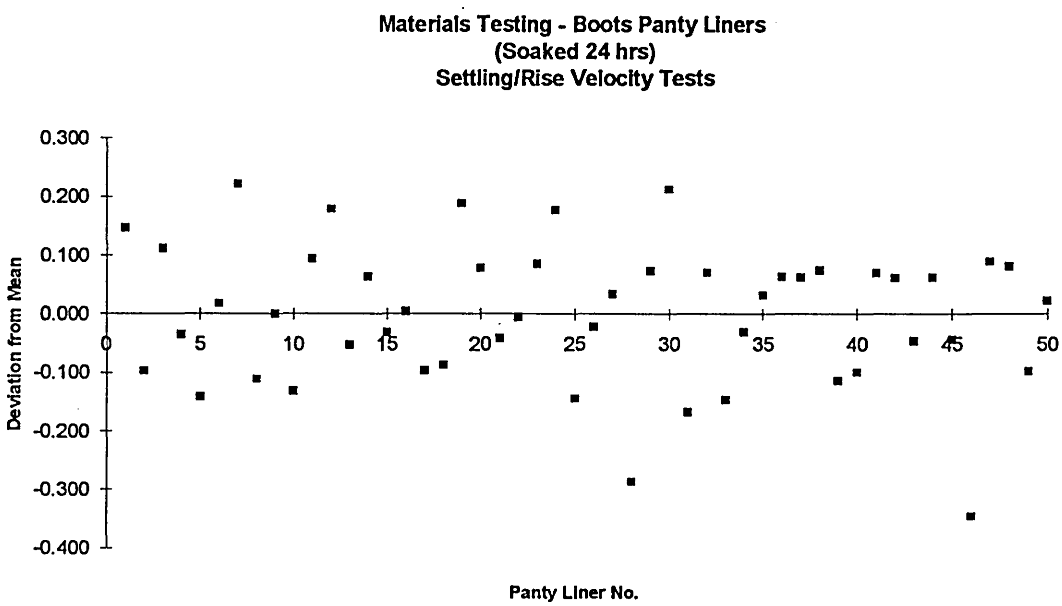


Figure 4.39

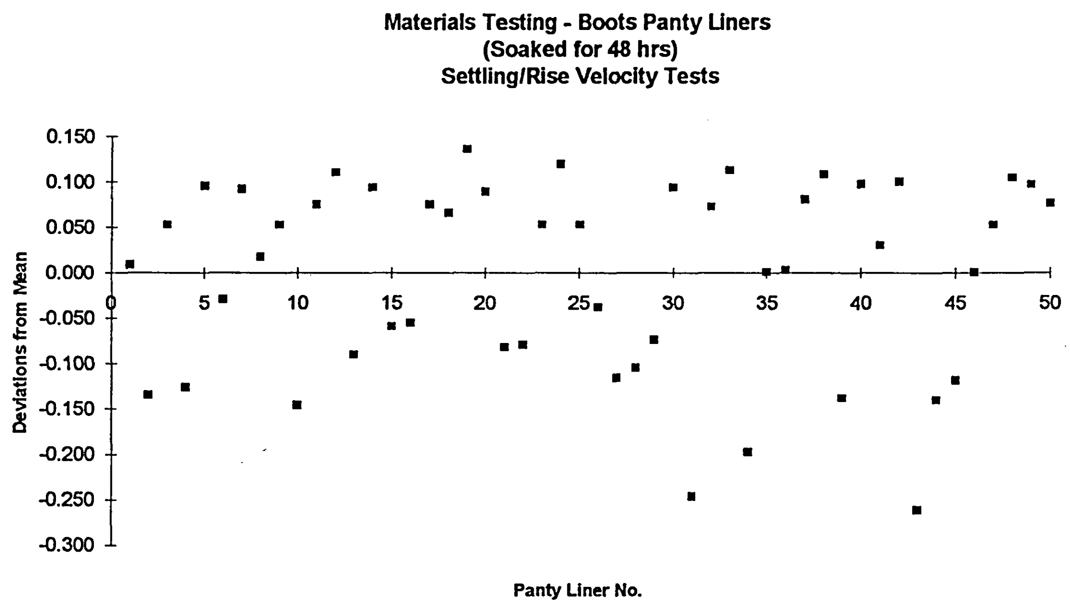


Figure 4.40

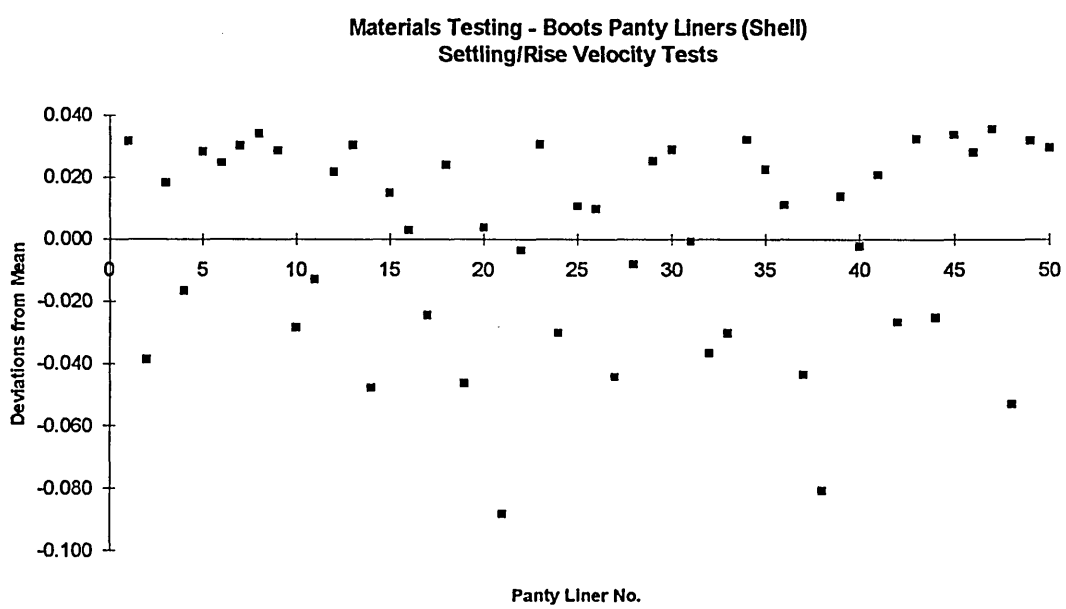


Figure 4.41

CHAPTER 5 HEAD LOSSES AT SCREENS

5.1 Introduction

Chapter 4 described full scale laboratory tests carried out on five screen meshes. The results of these tests showed that it was possible to reproduce the screen retention efficiencies found in the field. The laboratory tests could not, however, predict the screen head losses likely to be encountered in the field environment. Additional tests were carried out on the screen meshes to determine the screen head losses when the screening media was clean and when partially blinded.

5.2 Methodology

A 300 mm square re-circulating, glass-sided, flume in the Hydraulics Laboratory at Sheffield Hallam University was used for the tests, figures 5.1 and 5.2. The flume operates independently of the ring main and has its own pump and sump tank. The sump tank is positioned underneath the flume to one side and a wooden platform has been built above the sump tank to allow ease of access to the flume for measurements and observation. Steps at the upstream end of the flume provide access to the platform. A Kent turbine meter is fitted onto the system underneath the channel for measuring the flowrate in the flume. A dial gauge is provided on the meter to show the volume of water passing through the system. One revolution of the dial gauge is equal to 1000 litres of water passing through the system. A manually operated valve controls the flowrate. At the downstream end of the flume is a regulating weir which can be used to increase the depth of flow within the channel, figure 5.3. The gradient of the flume can also be altered using a jacking system which is located beneath the flume at the downstream end.

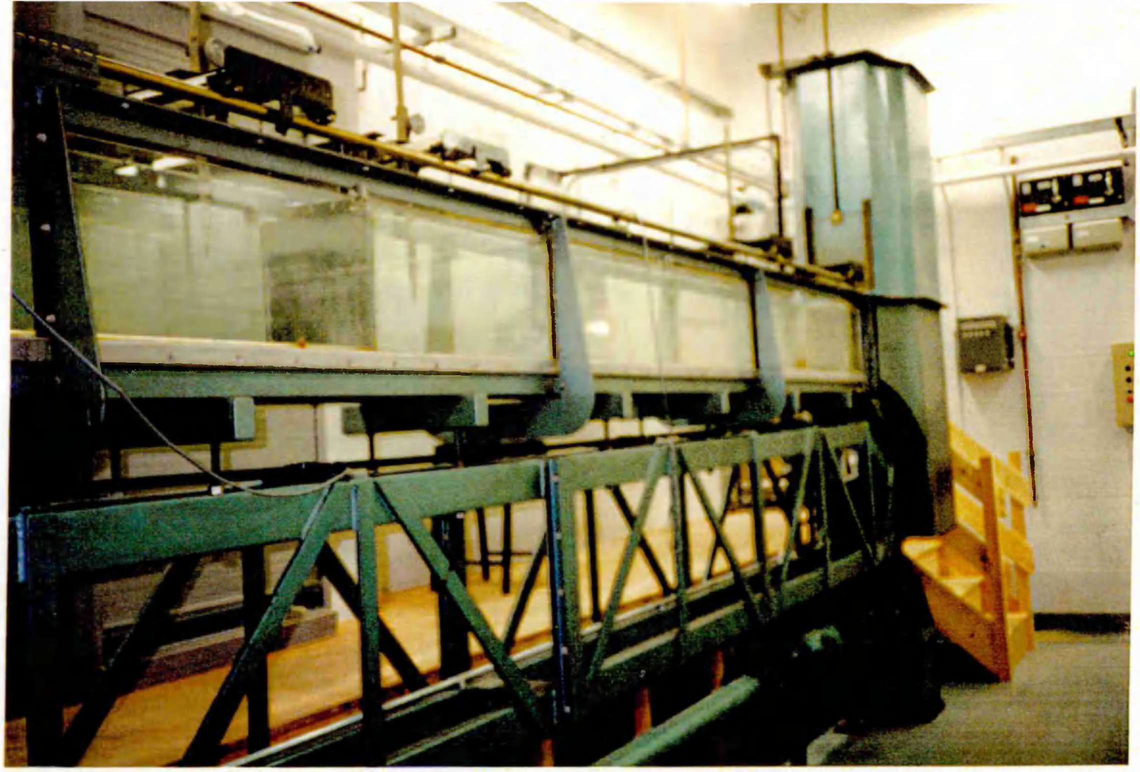


Figure 5.1 Glass-sided Flume

Figure 5.2 Glass-sided Flume

A 300 mm square steel frame was manufactured to hold each screen mesh. The screen mesh under test was fastened onto the steel frame using copper wire. The Copasac plastic mesh was attached to a one inch piece of square steel mesh using small nylon cable ties. This was then wired onto the steel frame. The steel frame was bolted onto a steel plate which was clamped across the top of the channel so that the screen mesh was held vertically in the channel, figure 5.4. The frame was then sealed down each side and along the base with silicone sealant to ensure all of the flow passed through the screen mesh. Two pointer gauges were positioned either side of the screen mesh to measure the depth of flow upstream and downstream of the screen mesh, figure 5.5. A pointer gauge reading of the bed of the channel either side of the test mesh was taken to establish a datum in order to calculate the depth of flow upstream and downstream. The flume was levelled using the jacking system and a spirit level.

Each screen mesh was tested clean and partially blinded using four weir positions downstream which were marked to ensure they were identical for each test. For each screen mesh test, the weir position was set to the first position, this being with the weir as low as possible. The control valve was then opened to allow 10% of the available flow to circulate the system. The flowrate was then measured by finding the time taken for 100 litres of water to pass through the system. The upstream water level and the downstream water level were then measured using the pointer gauges. The flowrate was then increased by 5% and the measurements repeated until the maximum 100% flow was passing through the system. The weir was then raised to the next position, to increase the depth of flow in the channel and to submerge the screen mesh, and the test repeated. Only one screen mesh was tested each day to allow time for the screen meshes to be changed and the silicone sealant to harden. When the screen mesh tests were carried out using the fourth weir position 100% flow was not possible. The depth of water in the flume between 75% and 85% flow (depending on the screen mesh) filled the channel and the

Figure 5.3 Regulating Weir

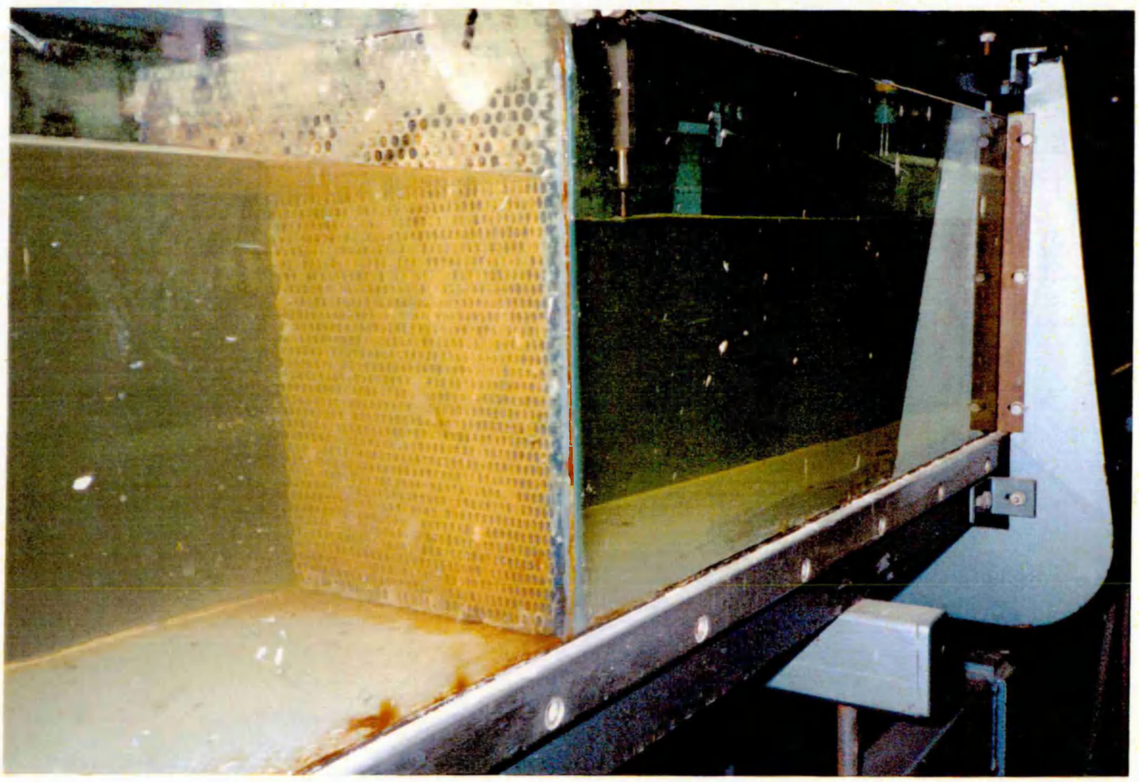


Figure 5.4 Screen mesh held vertically in channel

Figure 5.5 Pointer gauges used to measure depth of flow upstream and downstream of screen mesh

emergency cut-off was activated to prevent overspill.

Several attempts were made to partially blind the mesh screens in the full scale laboratory test rig used for the screen mesh tests in chapter 4. The same materials used for the fine material efficiency tests were used and the five screen meshes were loosely tied onto one of the larger screen meshes which was inserted into the first set of guides. The flow was then switched on and the fine material introduced into the flow between the baffle arrangement. The flow was left for 5 minutes before being turned off and the screens left to drain. It was found, however, that the degree of blinding on each screen varied greatly, and for the purposes of the head loss test it was felt that a more consistent amount of blinding was required. A rectangular tank was used to partially blind the screen meshes to achieve a similar degree of blinding on each. The rectangular tank was filled with water and the fine materials used for the laboratory tests in chapter 4 were mechanically agitated in 500 ml of water and added to the tank. The screen meshes were laid in the bottom of the tank and the water disturbed above them to ensure the fine material was dispersed within the fluid. Each screen mesh was then lifted up through the fine material suspension and removed from the tank. This provided a fine consistent covering over the face of the mesh. The five screen meshes were then laid across one of the larger screen meshes over the full scale laboratory channel and allowed to dry. After the partially blinded screen meshes had been tested they were allowed to dry again and the percentage of blinding (i.e. the reduction in open area caused by blinding) was assessed. Since the percentage of blinding was not consistent on the screen mesh face representative holes in the middle of the range of blinding were identified by eye. The opening of these representative holes was measured to obtain an average value of the reduction in open area.

5.3 Analysis

It was assumed that the flow pattern through each individual aperture in the screen mesh was like that of the flow through an orifice. Collectively the flow through the screen mesh can be represented by a classical analysis of orifice flow.

The analysis for the free flow case is as follows:

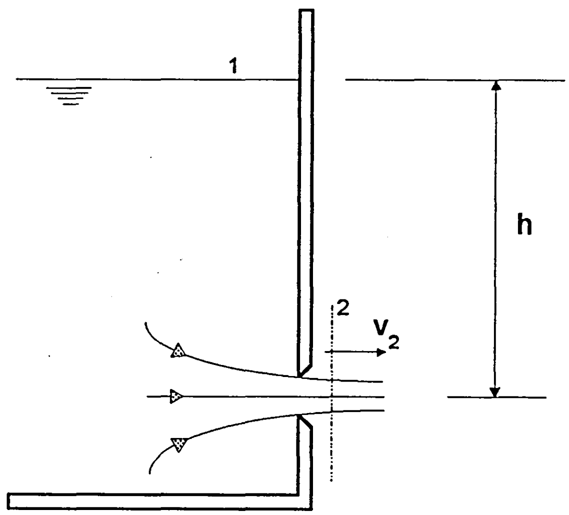


Figure 5.6 Free orifice flow

Applying the energy principle:

$$h + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = 0 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + \text{losses} \qquad (5.1)$$

With $p_1 = p_2$ (both atmospheric), assuming $v_1 \approx 0$ and ignoring losses we get:

$$\frac{v_2^2}{2g} = h \qquad (5.2)$$

or the velocity through the orifice, $v_2 = \sqrt{2gh}$ (5.3)

The analysis for the submerged case is as follows:

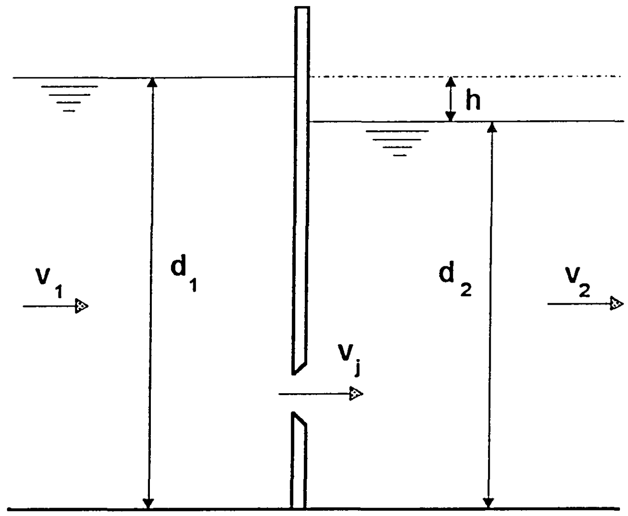


Figure 5.7 Submerged orifice flow

Applying the energy equation:

$$d_1 + \frac{v_1^2}{2g} = d_2 + \frac{v_2^2}{2g} + \text{losses} \qquad (5.4)$$

$$\text{losses} = \frac{v_j^2}{2g} \qquad (5.5)$$

If $d_2 \cong d_1$ (i.e. h is small)

$$v_2^2 \cong v_1^2 \qquad (5.6)$$

$$\therefore \; h = \frac{v_j^2}{2g} \qquad (5.7)$$

or the velocity through the orifice, $v_j = \sqrt{2gh}$ (5.8)

The discharge in both the free flow and submerged cases may be calculated by applying the continuity equation:

$$Q = v_j a \qquad (5.9)$$

Where a = area of jet

The actual velocity = $C_v \sqrt{2gh}$ where C_v is the coefficient of velocity defined as:

$$C_v = \text{actual velocity/theoretical velocity} \qquad (5.10)$$

The jet area is much less than the area of the orifice due to the contraction and the corresponding coefficient of contraction which is defined as:

$$C_c = \text{area of jet/ area of orifice, } a_o \qquad (5.11)$$

The velocity at the contraction of the jet, known as the vena contracta is normal to the cross section of the jet and hence the discharge can be written as:

$$\begin{aligned} Q &= \text{area of jet x velocity of jet (at vena contracta)} \\ &= C_c a_o \times C_v \sqrt{2gh} \\ &= C_d a_o \sqrt{2gh} \qquad (5.12) \end{aligned}$$

$$\begin{aligned} \text{where } C_d &= \text{coefficient of discharge} \\ &= \text{actual discharge/theoretical discharge} \\ &= C_c C_v \qquad (5.13) \end{aligned}$$

The equation used in the analysis was:

$$C_d = \frac{A_O \sqrt{2gh}}{Q} \qquad (5.14)$$

Where C_d = coefficient of discharge

A_o = open area of screen mesh in flow (m^2)

h = head loss (m)

Q = discharge through screen mesh (m^3/s)

A value of C_d was calculated using equation 5.9 for each measurement and the mean and standard deviation of the C_d values was found for each test.

The C_d values calculated from the submerged tests were then compared with the values obtained by using the resistance coefficients of grids, screens, porous layers and packings published in Flow Resistance: A Design Guide For Engineers; Chapter 8, Flow Through Barriers Uniformly Distributed Over The Channel Cross Section (Fried and Idelchik, 1989). The general guidelines state that the resistance coefficient of a perforated plate (grid) depends on:

the free-area coefficient $f = \sum \frac{f_{or}}{F_{gr}} = \frac{F_o}{F_1}$, (5.15)

Where F_o = clear area of the grid

F_1 = upstream cross-sectional area of flow

the shape of the orifice edges,

and the Reynolds number, $Re = \frac{v_{or}\, d_{or}}{\nu}$ (5.16)

Where v_{or} = velocity through orifice

d_{or} = diameter of orifice

ν = kinematic viscosity

The resistance coefficient for a thin-walled grid of perforated sheets or strips with sharp-edged orifices was defined as:

$$\zeta = \frac{\Delta p}{\rho v_1^2 / 2} = \left(0.707\sqrt{1-f} + 1-f\right)^2 \frac{1}{f^2} \quad (5.17)$$

Where ζ = resistance coefficient

f = free area coefficient

v_1 = upstream velocity

Therefore

$$\Delta p = \zeta \frac{1}{2} \rho v_1^2 \quad (5.18)$$

$$\rho g h = \zeta \frac{1}{2} \rho v_1^2$$

$$2 g h = \zeta v_1^2$$

$$v_1 = \frac{1}{\sqrt{\zeta}} \sqrt{2gh}$$

$$Q = v_1 F_1$$

$$Q = \frac{F_1}{\sqrt{\zeta}} \sqrt{2gh} \qquad (5.19)$$

Comparing with orifice formula,

$$Q = C_d F_0 \sqrt{2gh} \qquad (5.20)$$

where C_d = coefficient of discharge based on the

area of opening of the mesh F_0

Comparing Equation 5.19 with 5.20

$$\frac{F_1}{\zeta} = C_d F_0 \qquad (5.21)$$

$$C_d = \frac{F_1}{F_0 \sqrt{\zeta}} = \frac{1}{f\sqrt{\zeta}} \qquad (5.22)$$

5.4 Results

The percentage of blinding of the five screen meshes is presented in table 5.1. The tables of results for the screen mesh tests can be found in Appendix E.

Table 5.1 Percentage of Blinding for the Screen Meshes

Screen Mesh	% Open Area	% Blinding	% Open Area after Blinding
6.0 mm Copasac	74	50	37
6.4 mm Round Perforated	43	10	38.7
6.0 mm Round Polyurethane	49	50	24.5
6.0 mm Square Perforated	62	33	41.5
6.0 mm Square Staggered Perforated	52	40	31.2

5.5 Discussion

The five screen meshes were blinded in exactly the same way to achieve a uniform blinding over the face of each screening media. During the tests a proportion of the fine material which partially blinded the test screens was forced through the mesh apertures by the flow. It was found that this proportion of material forced through the apertures was different for each screen mesh. For each of the partially blinded screen mesh tests the percentage of blinding was allowed to achieve a steady state before the measurements were taken. The percentage of blinding was therefore assessed after testing had been completed and the screen meshes had dried. This made it easier to see the fine material and compare the five screens.

Figure 5.8 shows the raw data plot for the five clean screen meshes for the second weir position test. From this plot it was thought that the data may exhibit a power law relationship so log plots were produced to investigate this relationship.

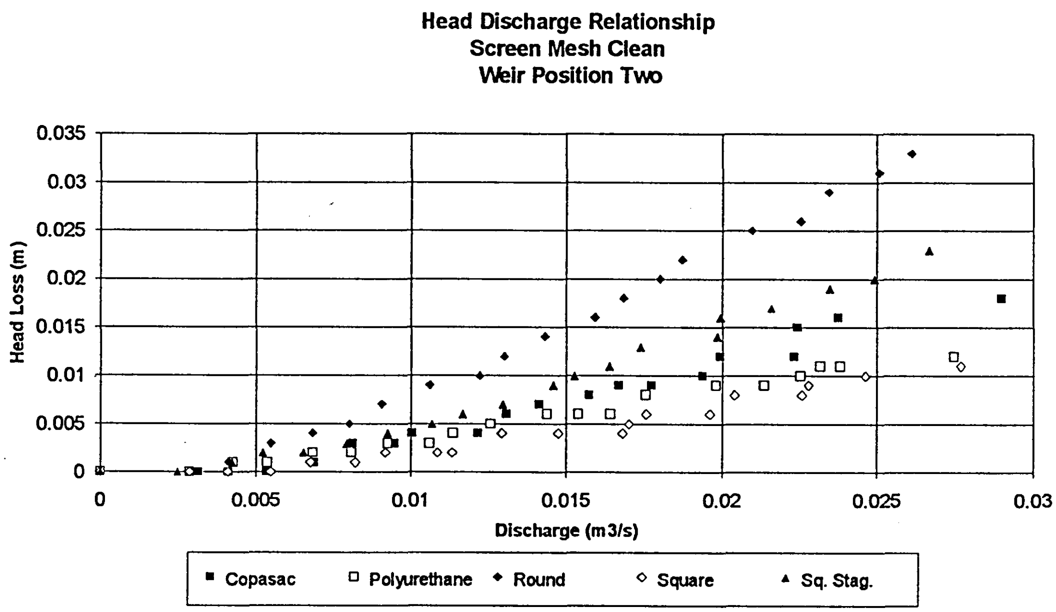


Figure 5.8 Head Discharge Relationship; Screen Meshes Clean (Weir Position 2)

Figures 5.9 to 5.28 show the head discharge relationship for the five screen meshes for all four weir positions. The results for the clean screen mesh and the partially blinded screen mesh, for each screening media, have been plotted on the same graph for comparison. The data has been plotted on a log scale to produce a straight line from a power law relationship. The lines of best fit were found using the method of least squares. As would be expected all the graphs show there are greater head losses when the screen mesh is partially blinded than when the screen mesh is clean. Figures 5.29 to 5.36 show the measured data plots for all five screen meshes plotted onto the same graph for comparison for all four weir positions both clean and partially blinded. The round steel screen mesh was found to have the greatest head losses for the no weir test when clean, followed by the square staggered steel screen mesh, the Copasac screen mesh and the polyurethane screen mesh, with the square steel screen mesh having the lowest. This was the case for the first submerged test (weir position one) with the round steel screen mesh having the greatest head losses and the square steel screen mesh the lowest. The round steel screen mesh was found to have the highest head losses for the second clean submerged test (weir position two) with, again the square steel screen mesh having the lowest. The polyurethane screen mesh was found to have higher head losses than the Copasac screen mesh at the start of the test but as the flowrate was increased this switched to the Copasac screen mesh having greater head losses. For the third submerged test (weir position three) the square steel, square staggered and polyurethane screen meshes were found to have comparable head losses with the Copasac screen mesh having lower head losses. The square steel screen mesh was found to have significantly lower head losses (almost half the value of the other screening media).

The gradients of the straight lines from the log plots for the clean screen mesh tests are shown in table 5.2. It was found that the round steel screen mesh had the steepest gradient for the no weir test and the polyurethane screen mesh the shallowest gradient. The results of the first submerged test (weir position one) showed that the Copasac screen mesh had the steepest gradient and the square staggered steel screen mesh the shallowest. The square steel screen mesh had the steepest gradient for the second submerged test (weir position two) with the polyurethane screen mesh having the shallowest. The results of the third submerged test (weir position three) showed that the round steel screen mesh had the steepest gradient and the round steel screen mesh the shallowest.

Table 5.2 Straight Line Gradients For Clean Screen Mesh Tests

Screen Mesh	No weir	Weir Position 1	Weir Position 2	Weir Position 3
Copasac	0.80	1.52	1.80	1.91
Round Perforated	0.88	1.45	1.72	2.10
Round Polyurethane	0.74	1.40	1.46	1.95
Square Perforated	0.86	1.42	1.83	1.55
Square Staggered Perforated	0.79	1.34	1.67	1.92

With the partially blinded no weir tests the polyurethane screen mesh had the largest head losses, followed by the round steel screen mesh, the Copasac screen mesh and the square staggered screen mesh. The square steel screen mesh was found to have the smallest head losses, again these were almost half the values of the other screening media. For the first submerged test, the polyurethane screen mesh was found to have the greatest head losses, the round steel, square staggered steel and Copasac screen meshes were found to have comparable head losses. The square steel screen mesh was again found to have the lowest head losses. With the other two submerged tests (weir positions two and three), the polyurethane screen mesh was found to have head loss values almost double the value of the other screening media with the other screen meshes having comparable head losses.

The gradients of the straight lines for the partially blinded screen mesh tests are shown in table 5.3. The Copasac screen mesh was found to have the steepest gradient for the no weir tests with the square steel screen mesh having the shallowest gradient. For the submerged tests, it was found that the round steel screen mesh had the steepest gradient and the polyurethane screen mesh the shallowest gradient.

Table 5.3 Straight Line Gradients For Partially Blinded Screen Mesh Tests

Screen Mesh	No weir	Weir Position 1	Weir Position 2	Weir Position 3
Copasac	0.90	1.23	1.50	1.52
Round Perforated	0.70	1.30	1.90	2.17
Round Polyurethane	0.74	1.07	1.35	1.44
Square Perforated	0.62	1.27	1.51	1.75
Square Staggered Perforated	0.82	1.06	1.70	1.97

In summary, the round steel screen mesh had the greatest head losses for the clean head loss tests, the polyurethane screen mesh had the greatest head losses for the partially blinded head loss tests and the square steel screen mesh had the lowest head losses for both tests.

The log plots have been used to explore the appropriateness of the orifice theory. The results of the partially drowned cases do not follow a square law relationship.

This shows that the application of the orifice theory is not appropriate for the partially drowned cases, where the weir is low or non existent (no weir case). The results from the no weir tests have been plotted separately from the submerged cases as the orifice theory is not appropriate in this case. The results from the drowned case follow a square law relationship and compare well with the orifice theory. In practice the fully drowned case would be present in most screen installations.

Figures 5.37 to 5.46 show the relationship between Cd (coefficient of discharge) and head loss for the submerged tests on the five screen meshes together with the values calculated from the Design Guide (Fried and Idelchik, 1989). The tests have produced results which are comparable to the results obtained by using the Design Guide (Fried and Idelchik, 1989). It can be seen that the Design Guide approach produces the same value of C_d, regardless of the head loss. However, the results from the laboratory tests show that the value of C_d decreases as the head loss increases. This is a classic coefficient of discharge/head loss relationship (Balmforth, 1978). Figure 5.37 shows there is a difference between the measured results and those calculated from the Design Guide (Fried and Idelchik, 1989) for the clean Copasac screen mesh, the measured values of C_d being lower than the Design Guide (Fried and Idelchik, 1989). However, figure 5.42 shows that the measured values for the partially blinded Copasac screen mesh give comparable results. The difference in the two results could be explained by the irregular shape of the plastic mesh. The woven plastic threads of the mesh produce a very flexible, irregular surface which provides a 3D surface as opposed to the 2D surface which the theory assumes. The blinding effect masks the 3D surface and provides a texture which is closer to a 2D surface. The results are therefore closer to the design guide (Fried and Idelchik, 1989) when the Copasac is partially blinded than when the Copasac is clean. For the clean polyurethane 9 mm thick screen mesh the grid made of thickened or perforated thick plate was used to calculate the design guide value of C_d. This was found to compare well with the measured results, figure 5.38. Initially the design guide value of C_d for the partially blinded case was calculated assuming a grid with rounded orifice edges, the rounded edges being the effect of the partial blinding. This produced a value of C_d which was greater than the measured value C_d. The design guide value of C_d was then calculated assuming a grid made of thickened laths or perforated thick plate as used for the clean polyurethane mesh. This value of C_d was found to fit well with the measured value, figure 5.43. This shows that the polyurethane screen mesh retains its thickness characteristics when blinded. The partial blinding only reduces the hole diameter it does not alter the effective geometry of the aperture.

Figures 5.37 to 5.46 show that the values of C_d for the measured data are comparable with the data calculated from the Design Guide (Fried and Idelchik, 1989). The design Guide value of C_d for the clean square staggered screen mesh is marginally higher than those measured for this screening media, figure 5.41. This was then found to be lower for the partially blinded case, figure 5.46. These results illustrate that the method used in the Design Guide (Fried and Idelchik, 1989) produces an average value of C_d for varying head loss. The laboratory results have provided a better representation of what actually happens to the screen mesh as the flowrate and thus the head loss increase. However, the results have produced C_d values which are similar to the design guide and in practice the design guide method would be acceptable for calculating head losses.

Head Loss Measurements in 12" flume

Head Discharge Relationship

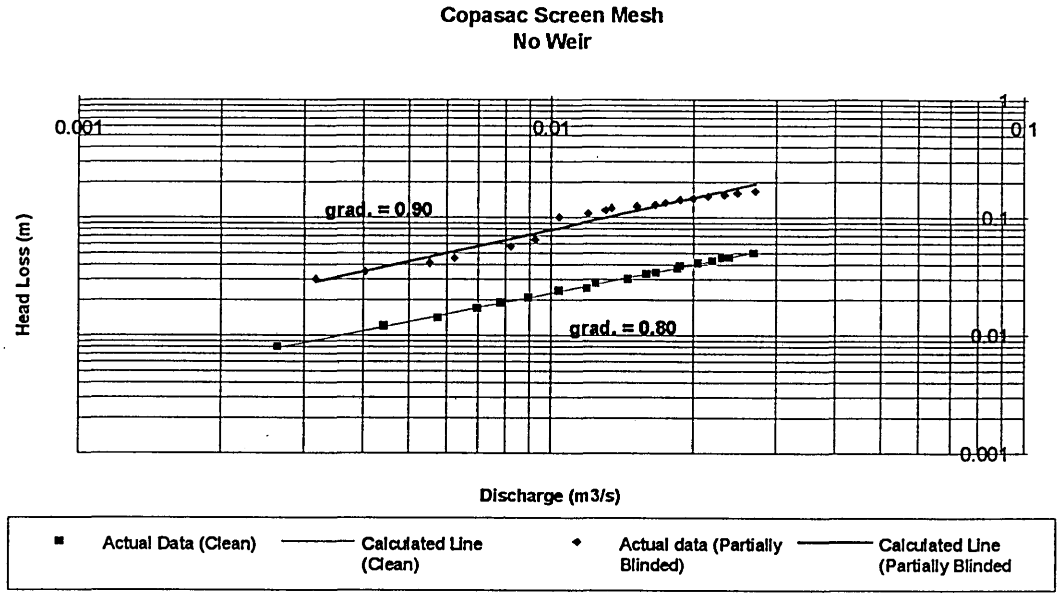


Figure 5.9

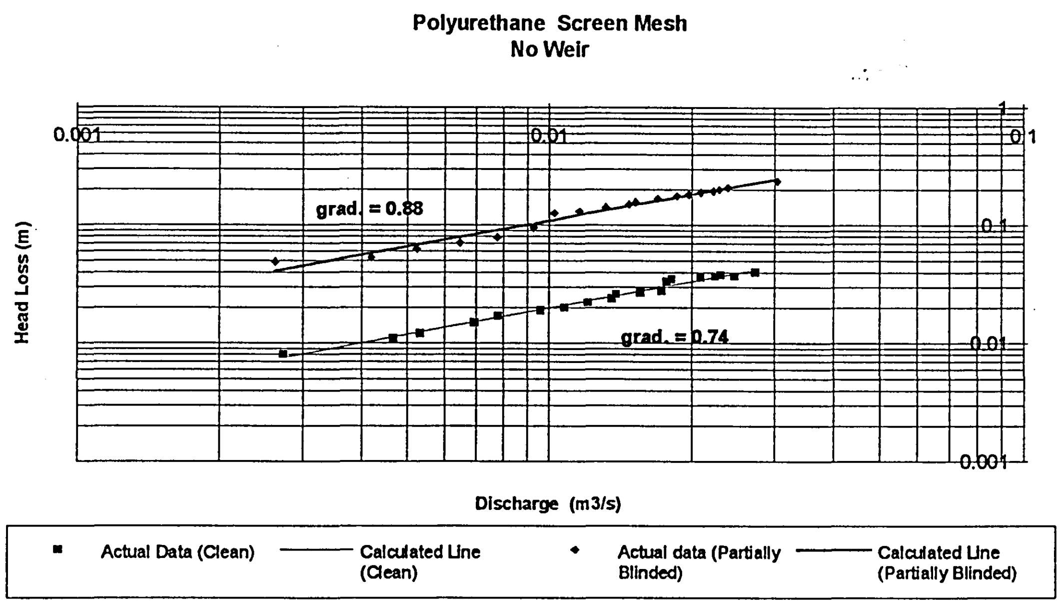


Figure 5.10

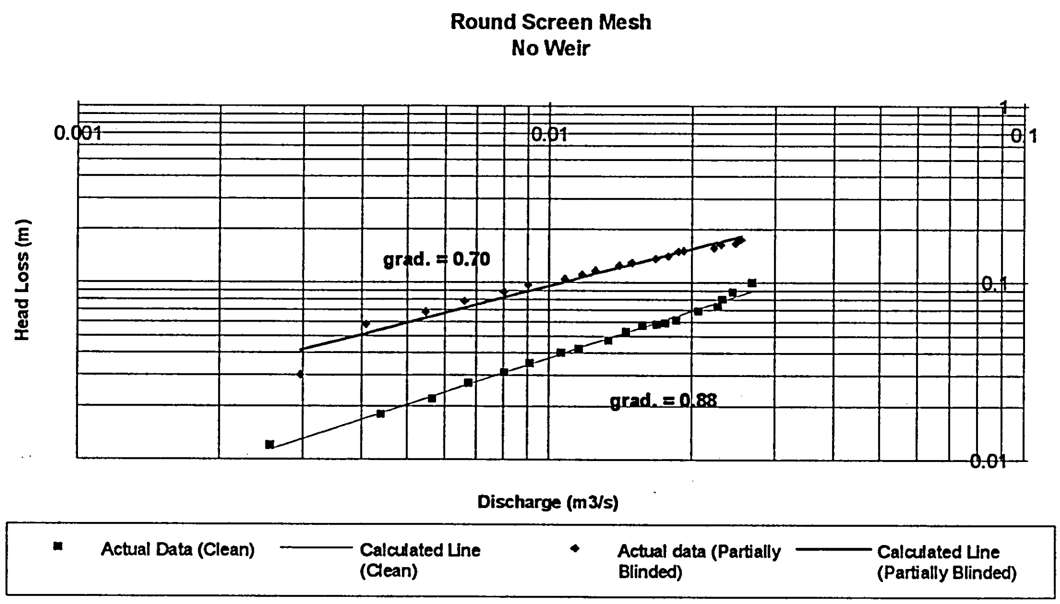


Figure 5.11

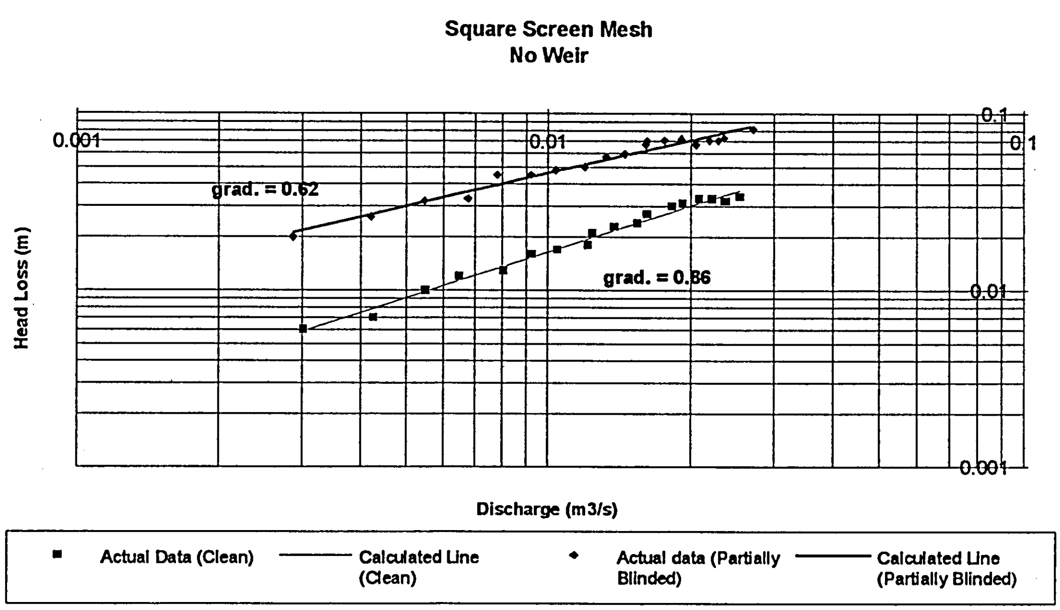


Figure 5.12

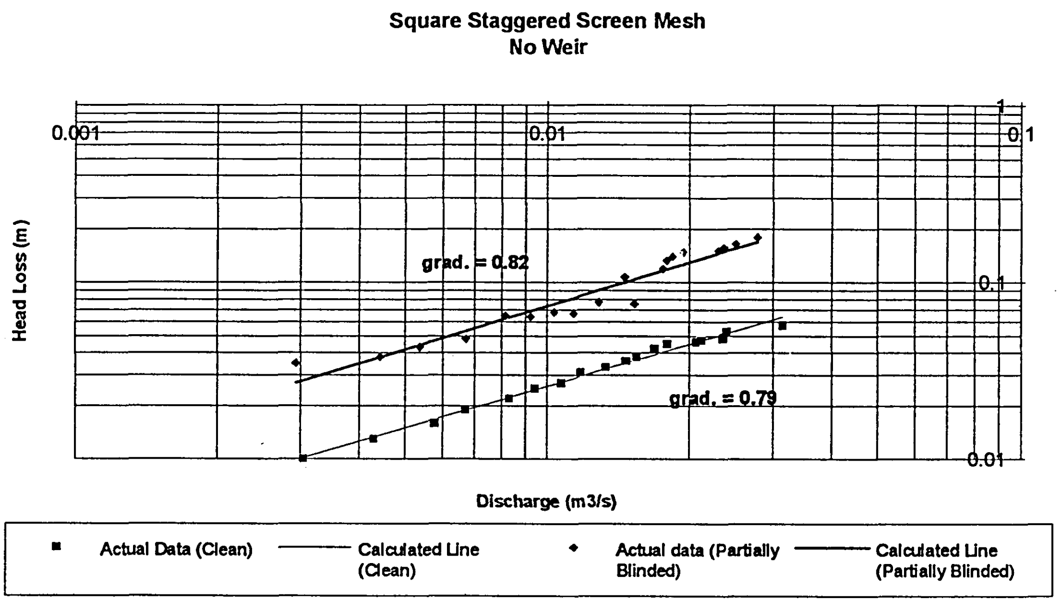


Figure 5.13

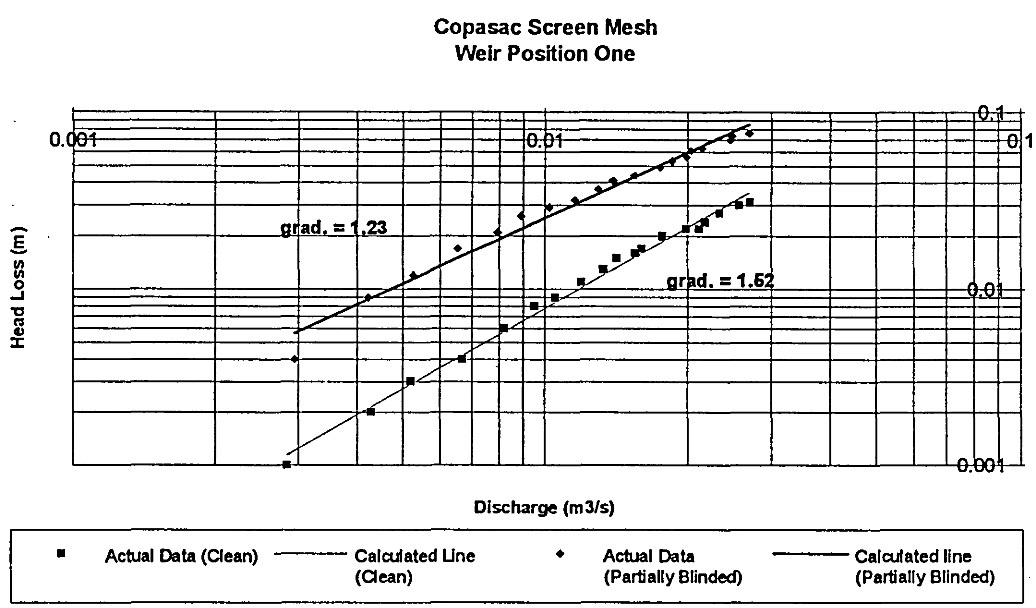


Figure 5.14

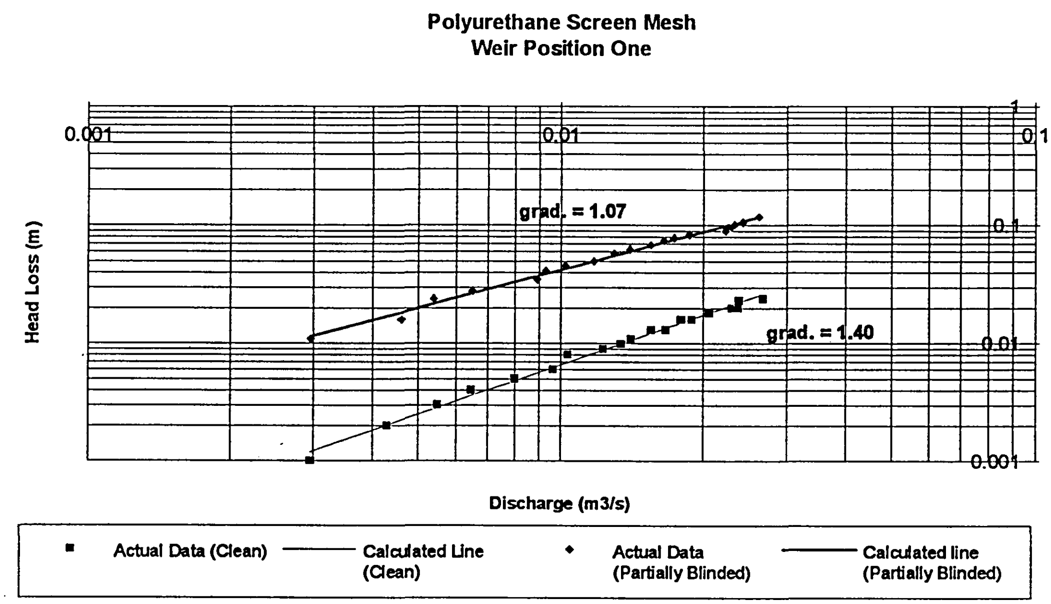


Figure 5.15

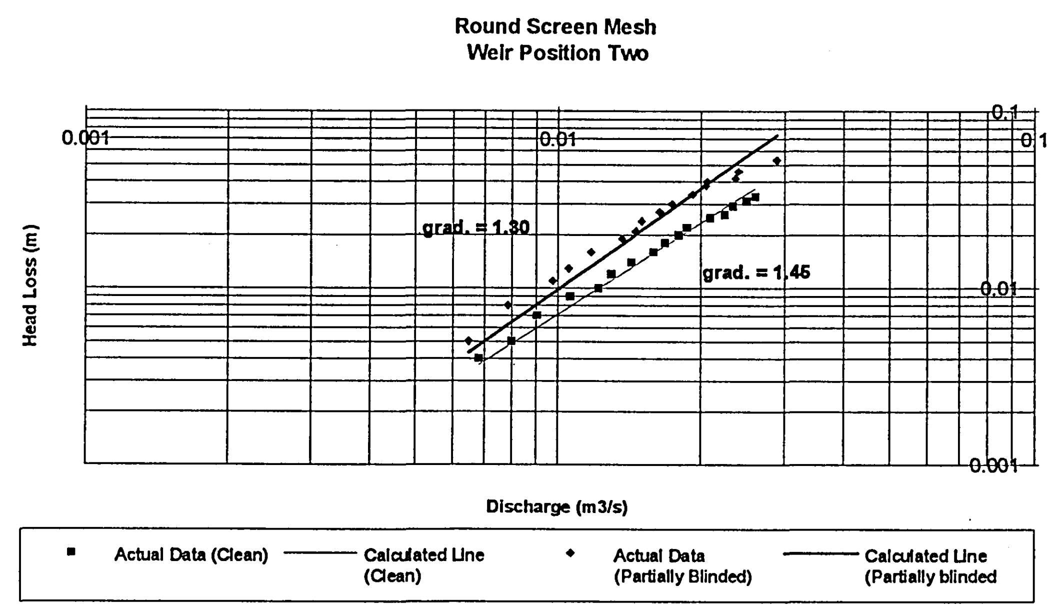


Figure 5.16

Square Screen Mesh
Weir Position One

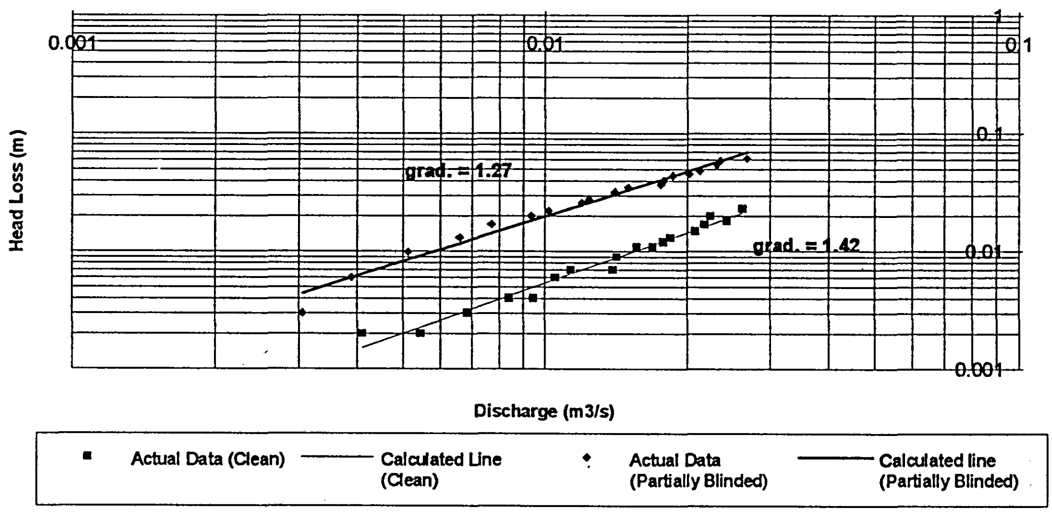


Figure 5.17

Square Staggered Screen Mesh
Weir Position One

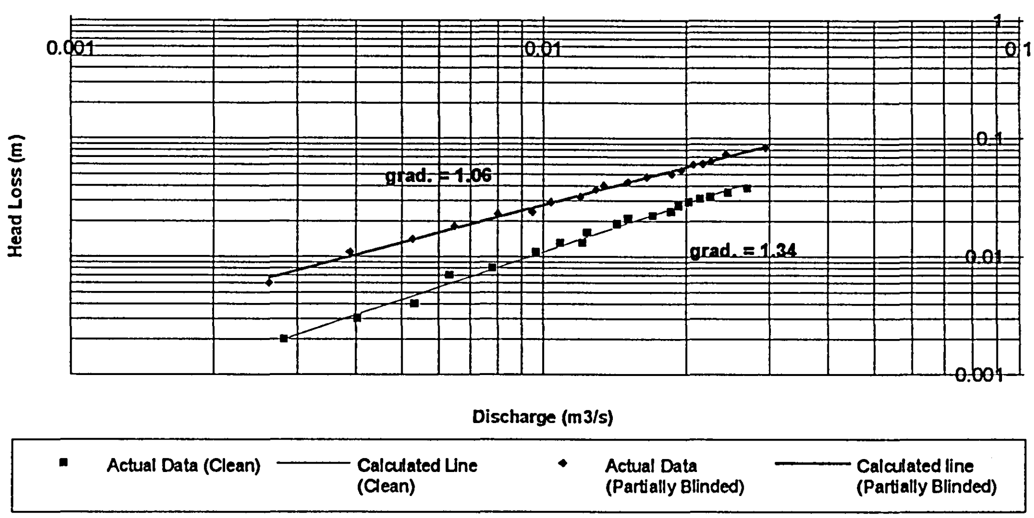


Figure 5.18

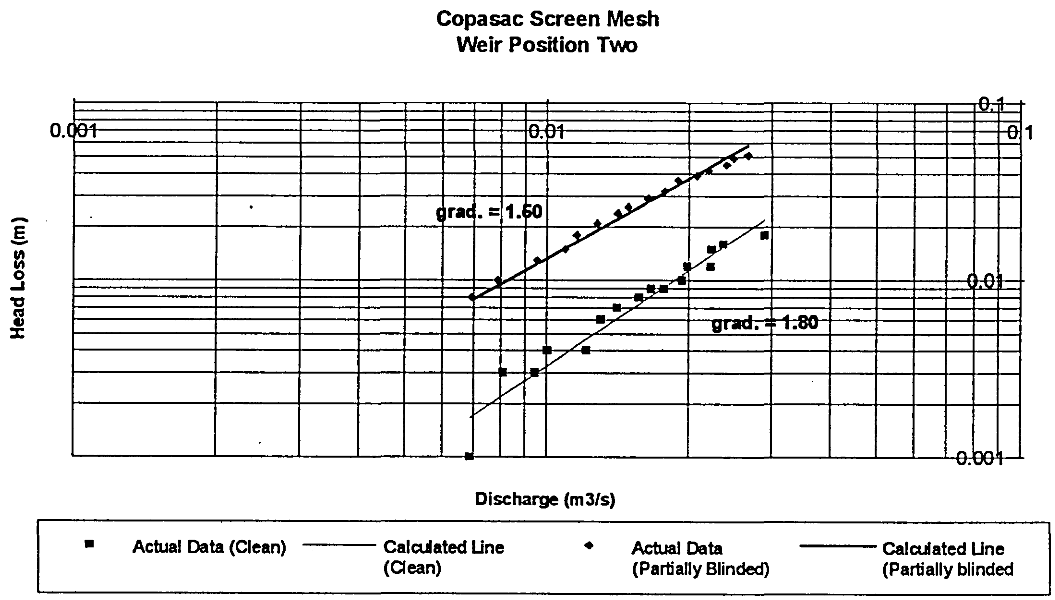


Figure 5.19

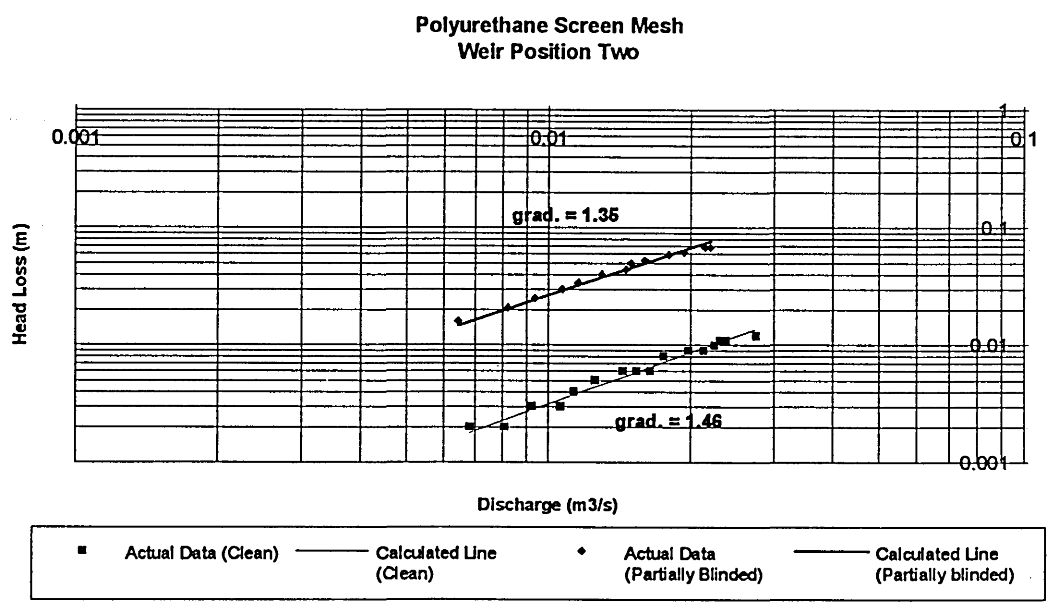


Figure 5.20

Round Screen Mesh
Weir Position Two

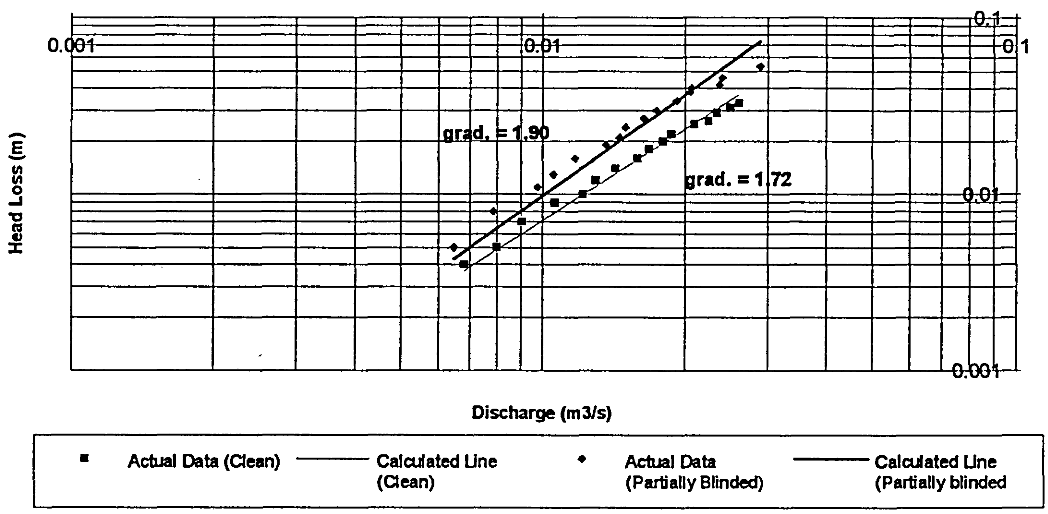


Figure 5.21

Square Screen Mesh
Weir Position Two

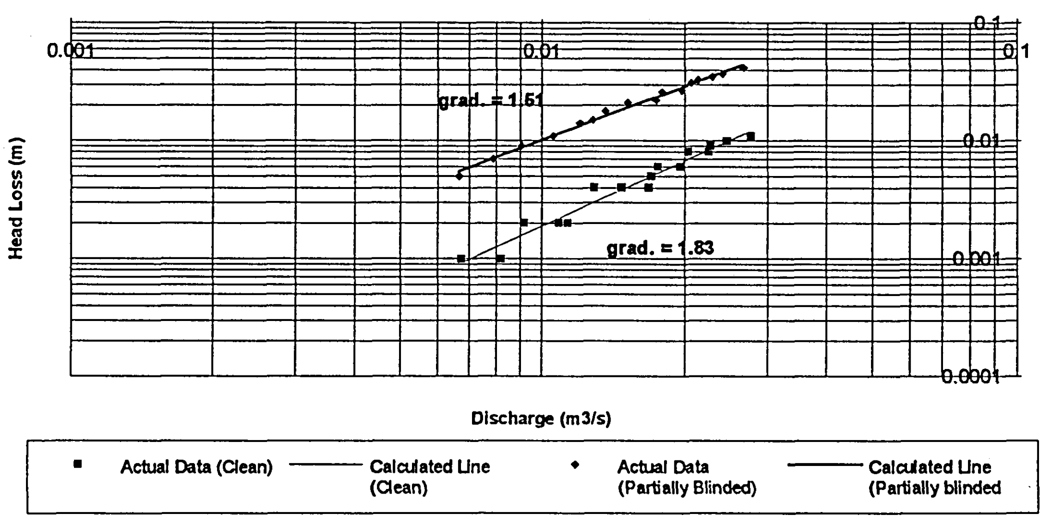


Figure 5.22

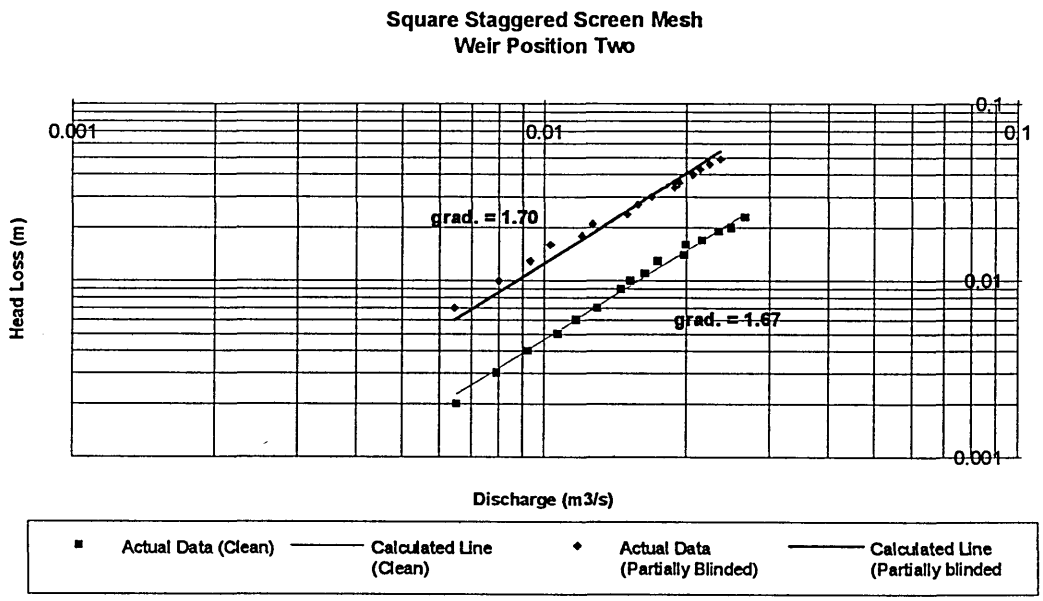


Figure 5.23

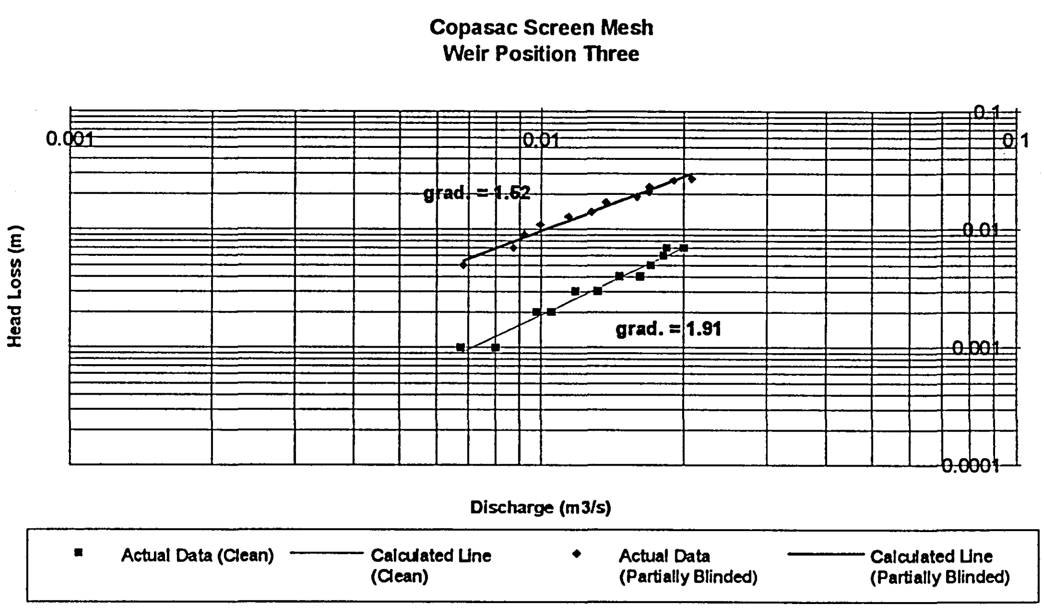


Figure 5.24

Polyurethane Screen Mesh
Weir Position Three

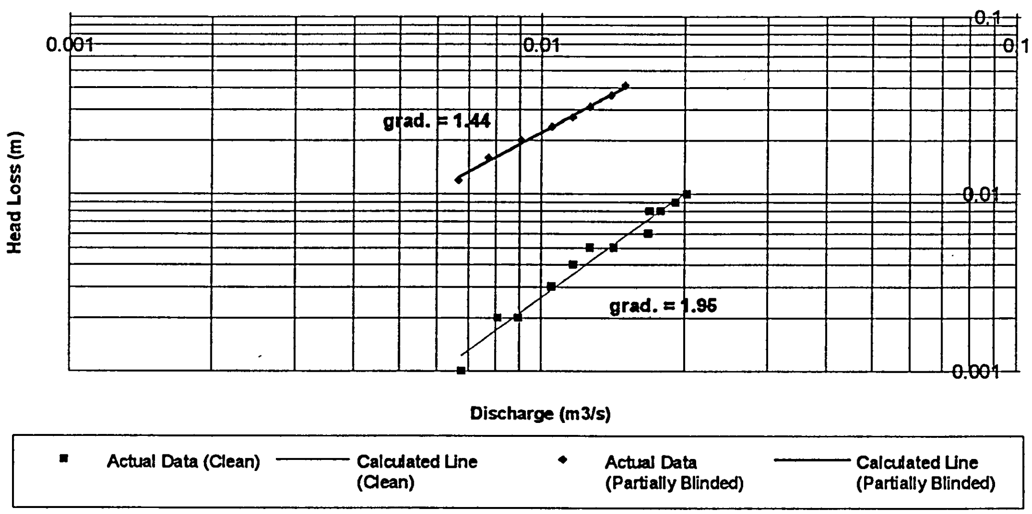


Figure 5.25

Round Screen Mesh
Weir Position Three

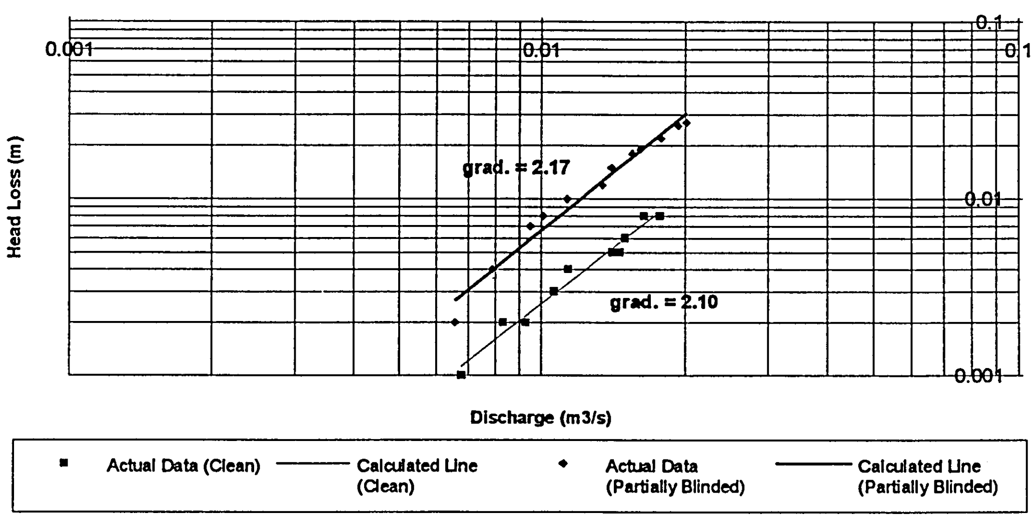


Figure 5.26

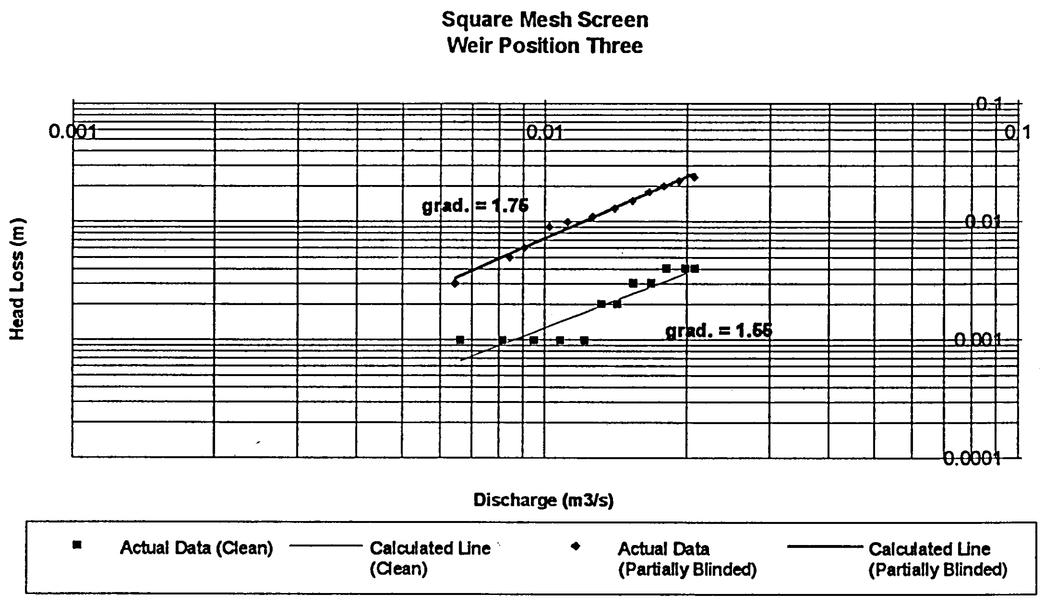


Figure 5.27

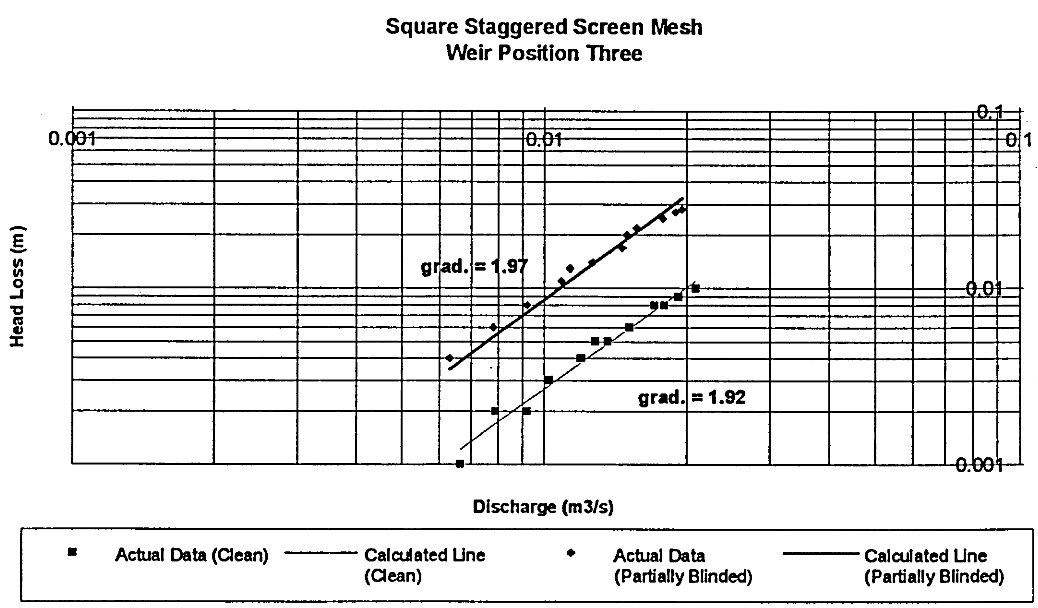


Figure 5.28

Head Loss Measurements in 12" flume

Head Discharge Relationship (Measured)

Comparison between screen meshes (clean)

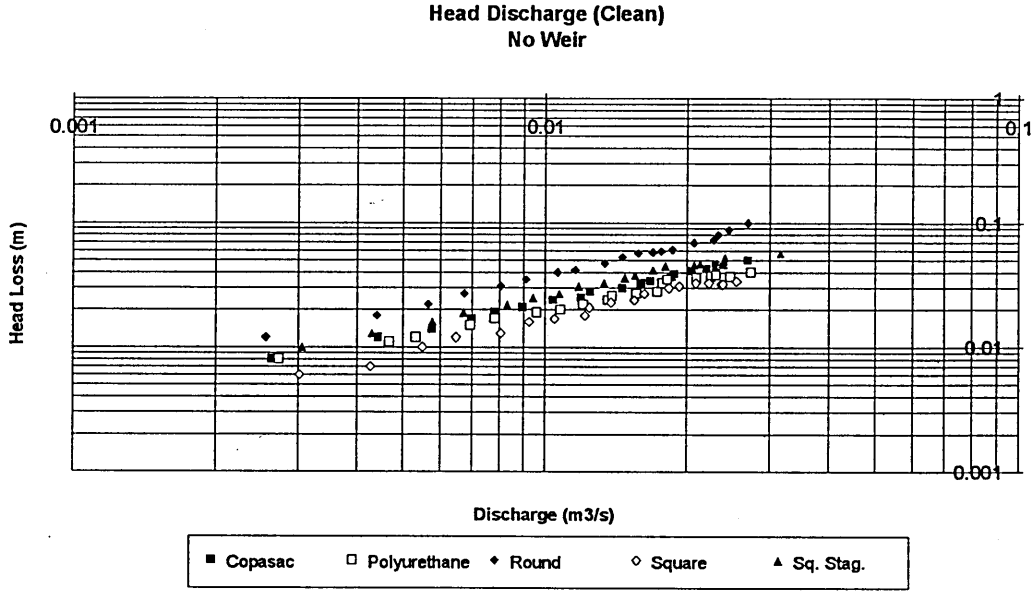


Figure 5.29

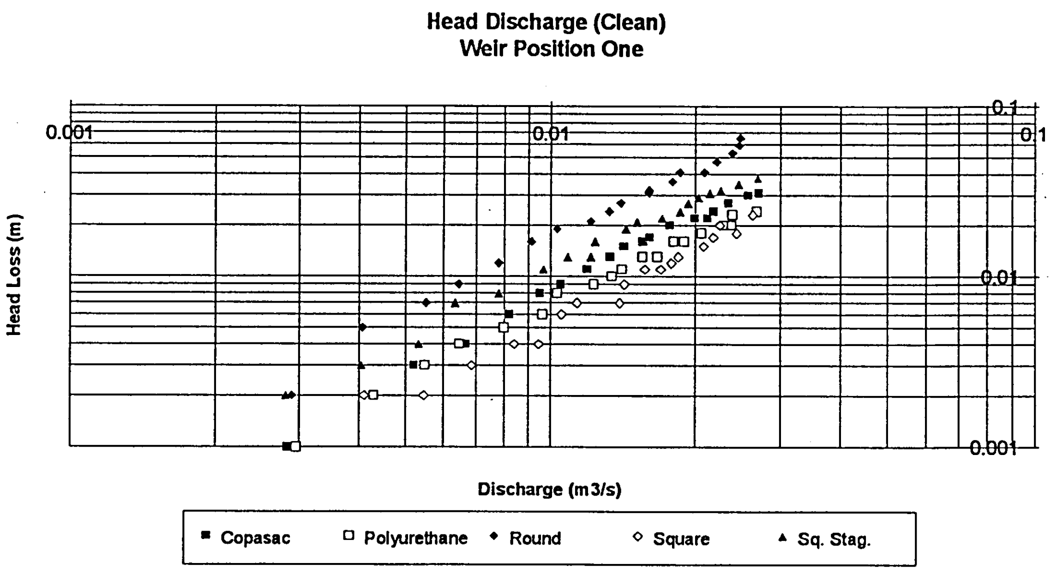


Figure 5.30

Head Discharge (Clean)
Weir Position Two

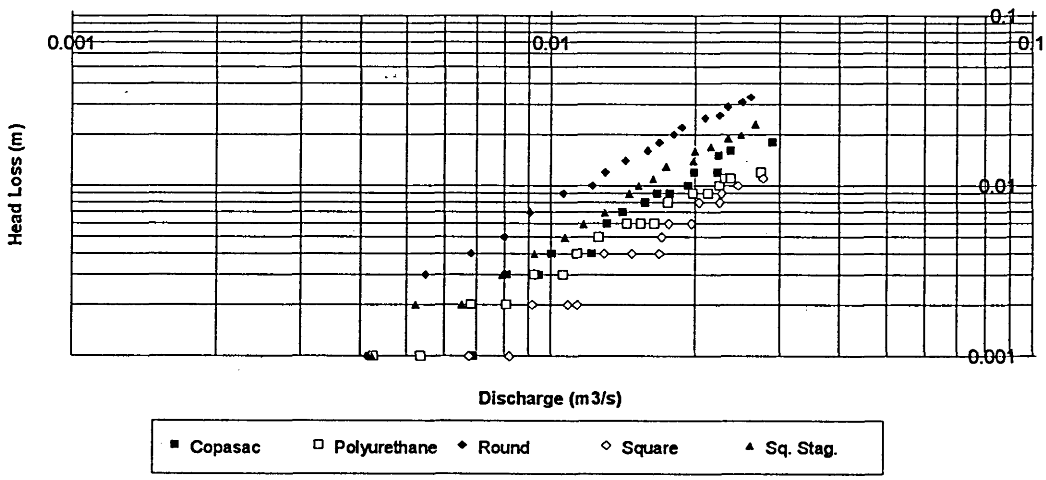


Figure 5.31

Head Discharge (Clean)
Weir Position Three

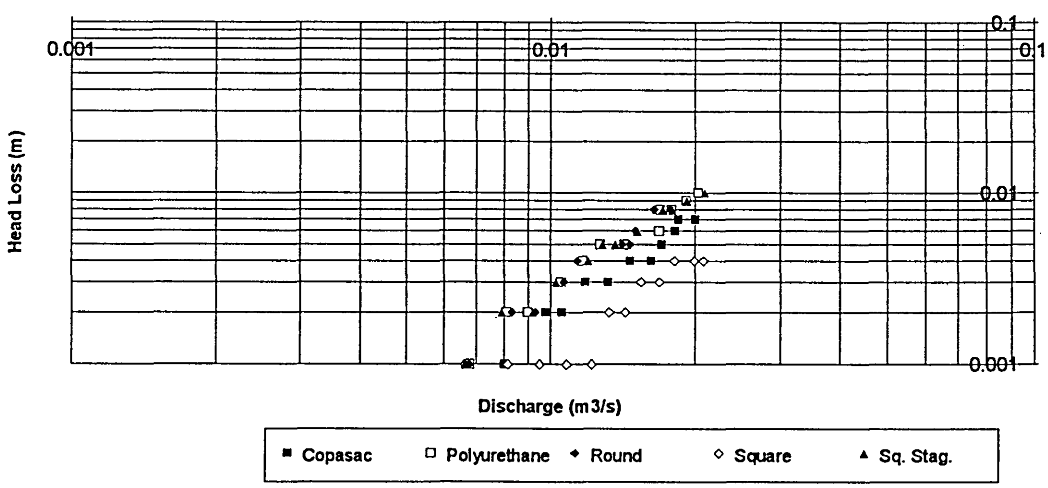


Figure 5.32

Head Loss Measurements in 12" flume

Head Discharge Relationship (Measured)

Comparison between screen meshes (partially blinded)

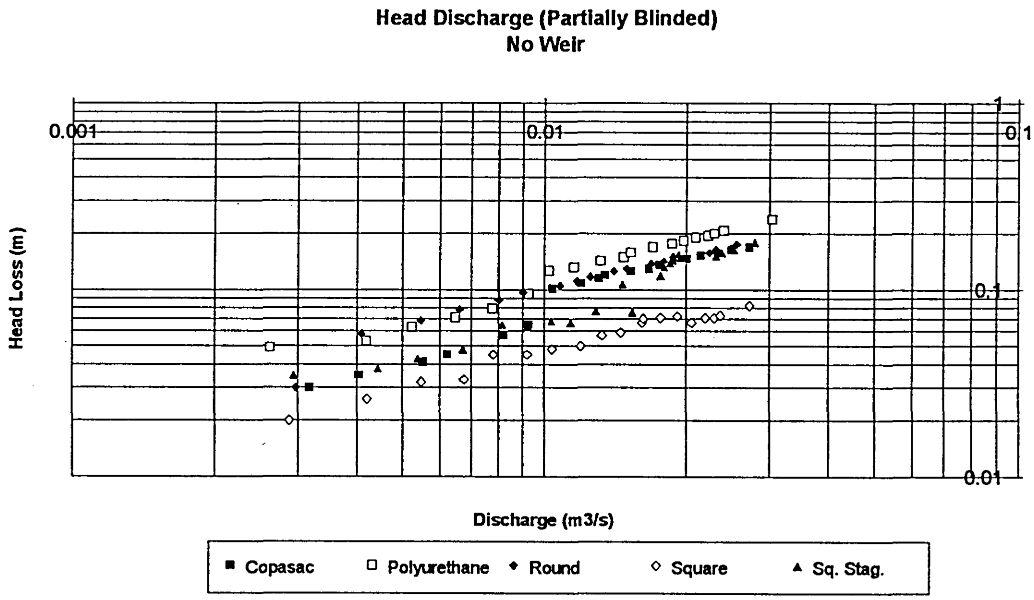


Figure 5.33

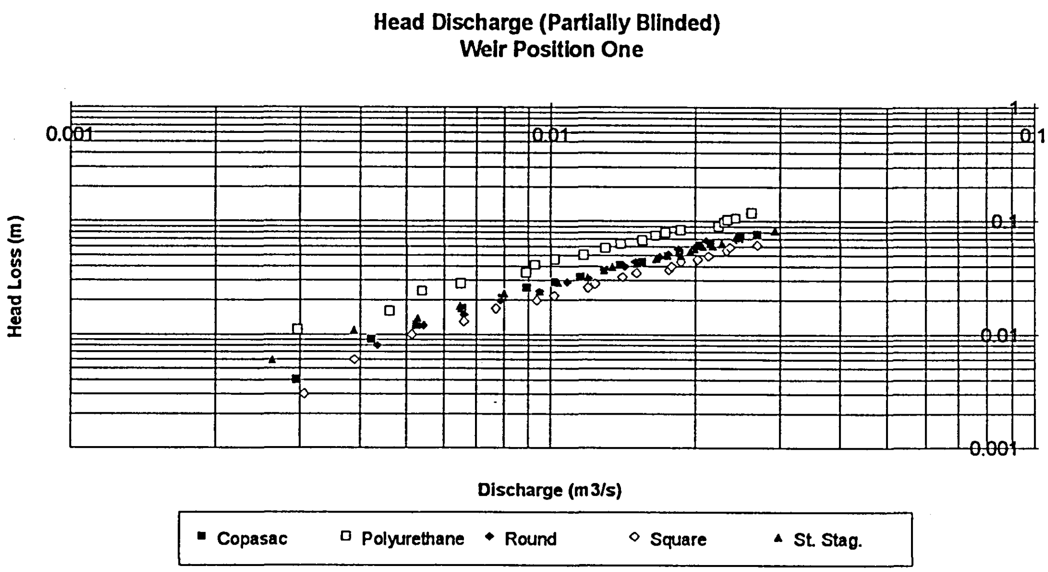


Figure 5.34

Head Discharge (Partially Blinded)
Weir Position Two

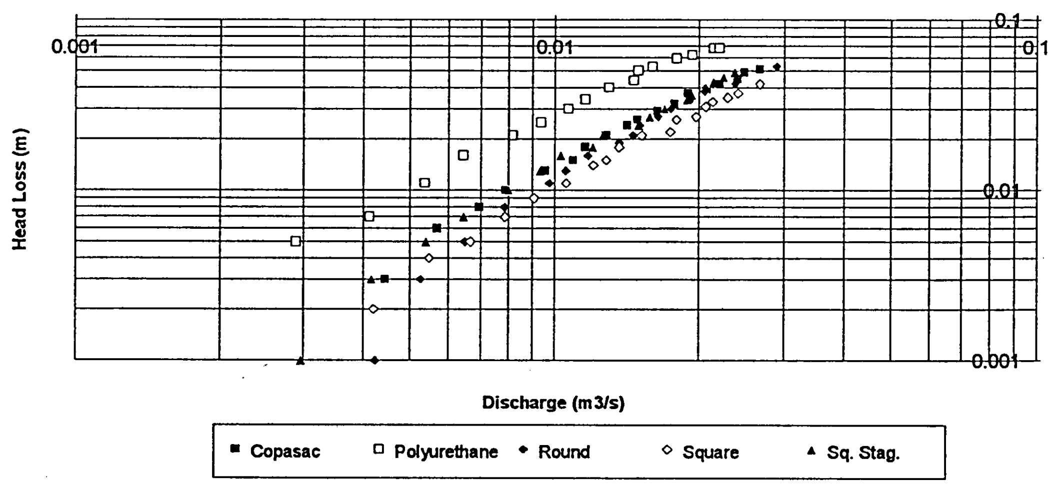


Figure 5.35

Head Discharge (Partially Blinded)
Weir Position Three

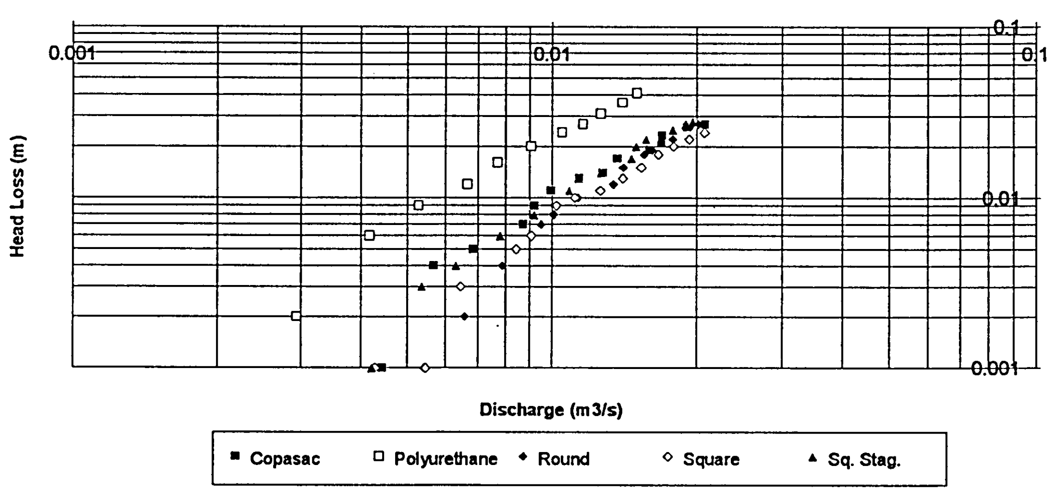


Figure 5.36

12" Flume Laboratory Tests

Relationship between C_d and Head Loss

Screen Mesh Clean

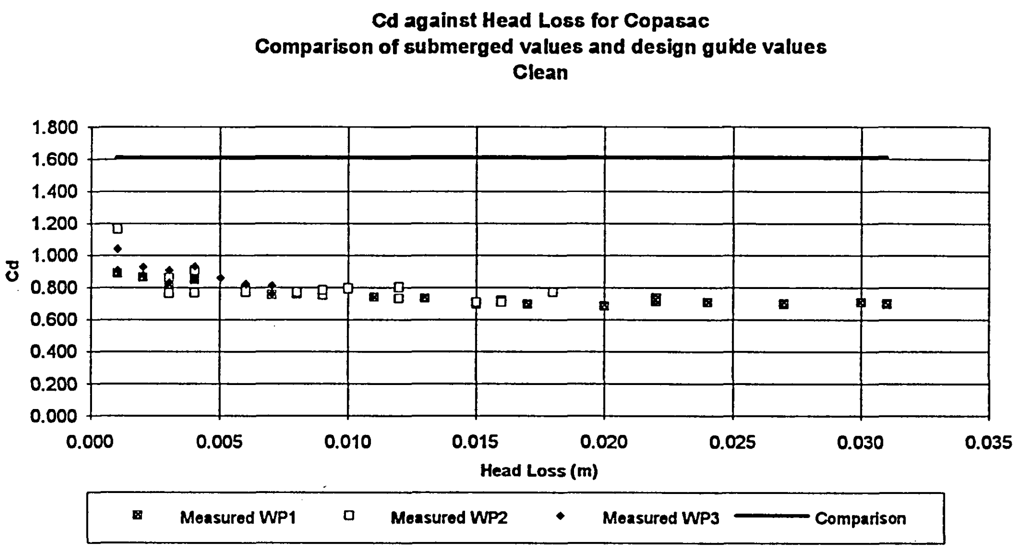


Figure 5.37

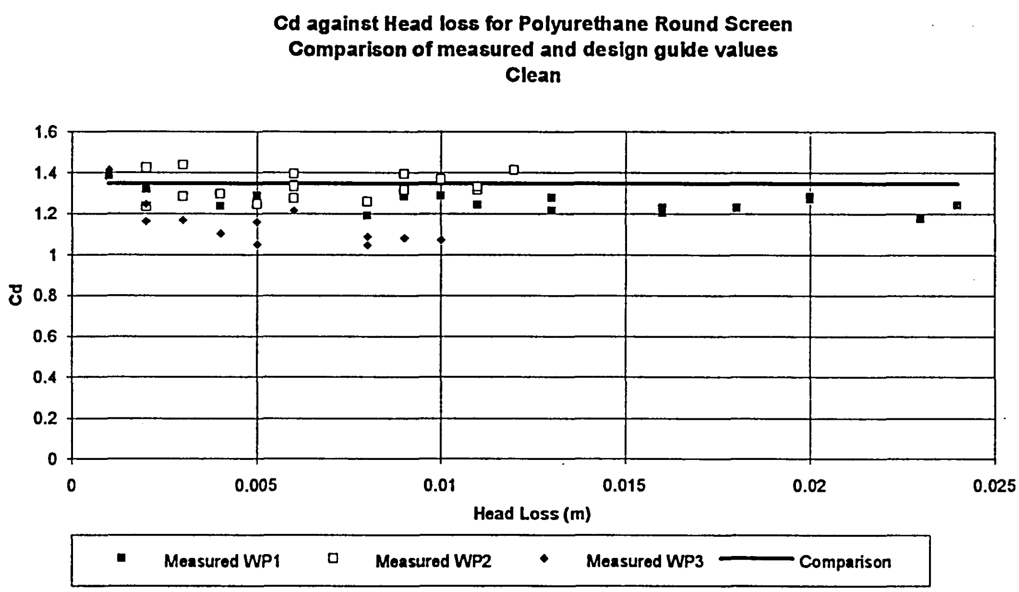


Figure 5.38

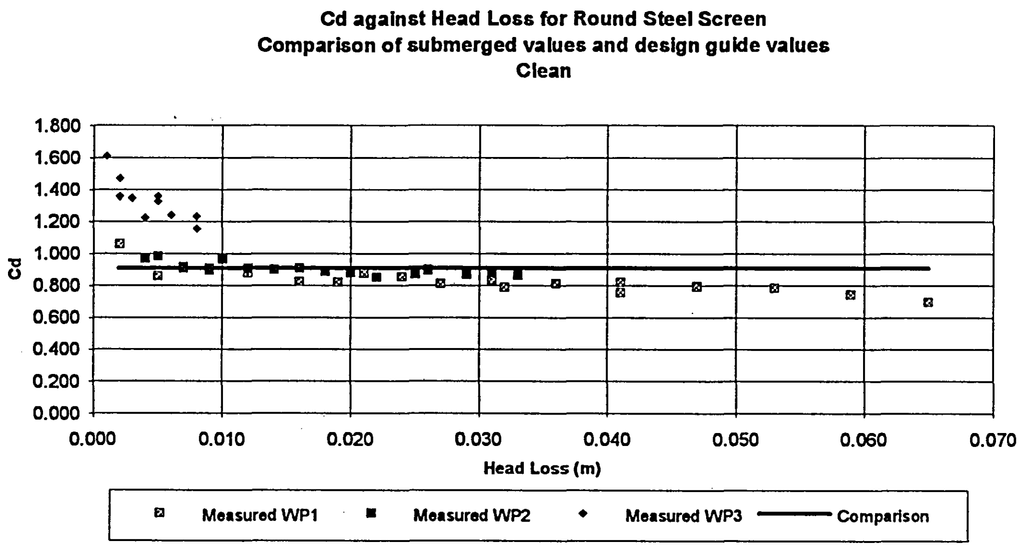


Figure 5.39

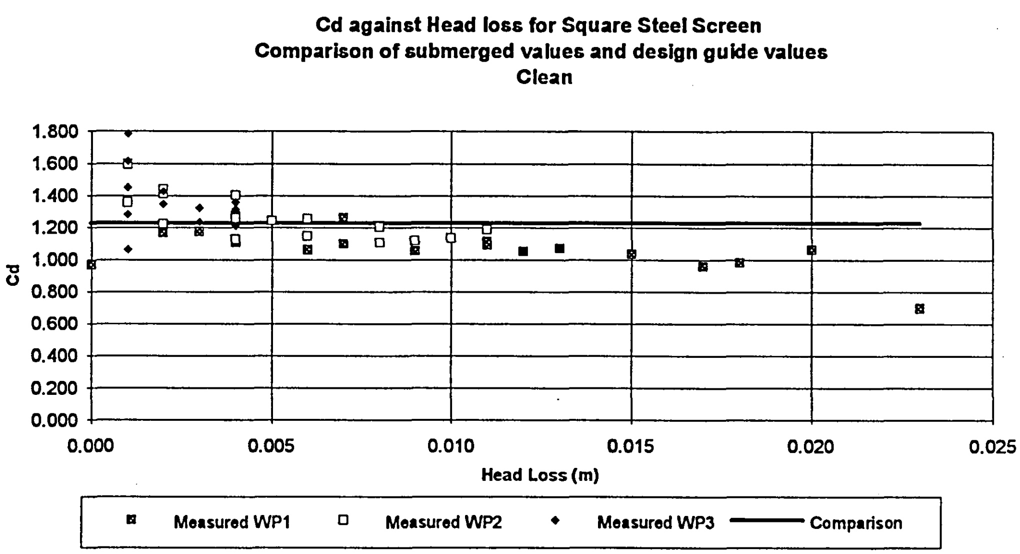


Figure 5.40

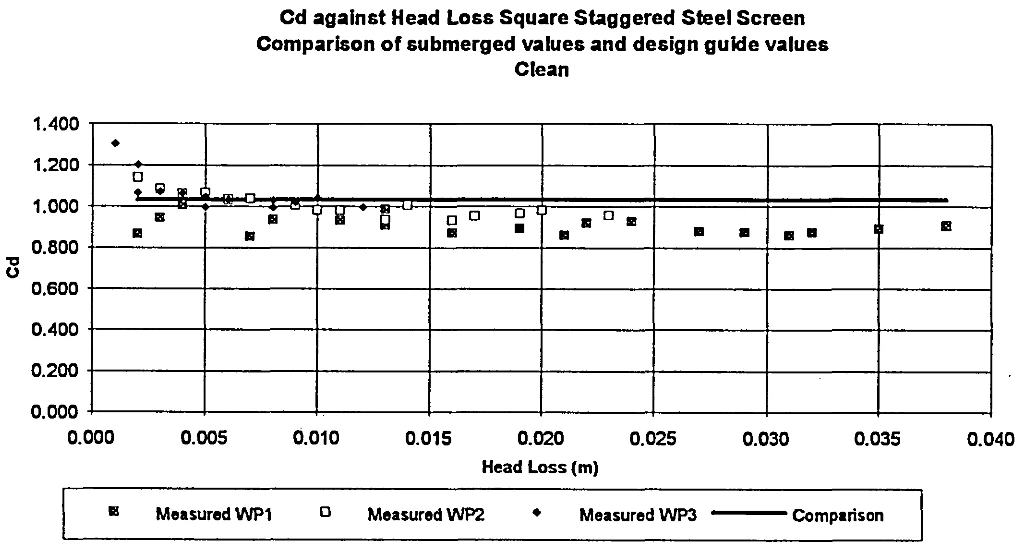

Cd against Head Loss Square Staggered Steel Screen
Comparison of submerged values and design guide values
Clean
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Cd
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Head Loss (m)
Measured WP1
Measured WP2
Measured WP3
Comparison

Figure 5.41

12" Flume Laboratory Tests

Relationship between C_d and Head Loss

Screen Mesh Partially Blinded

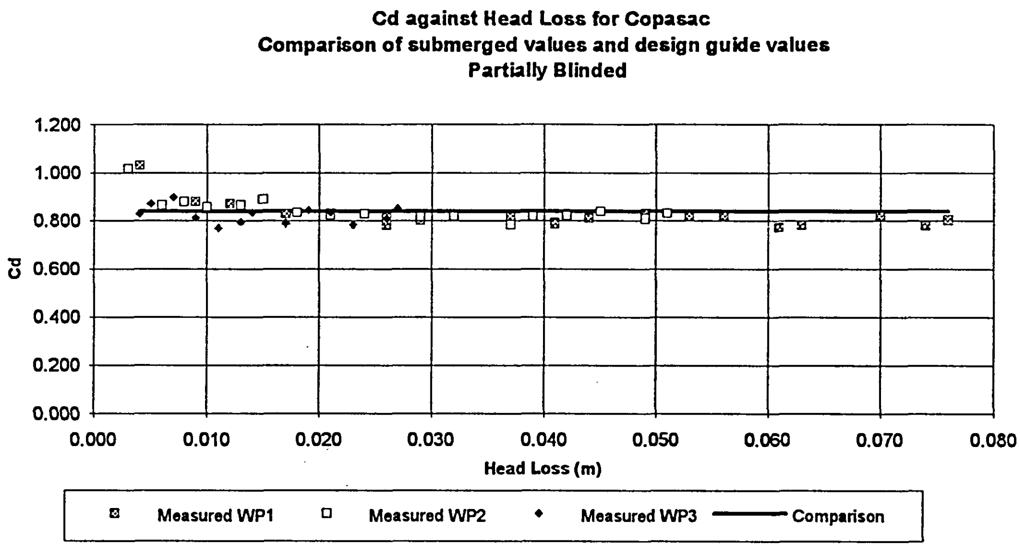


Figure 5.42

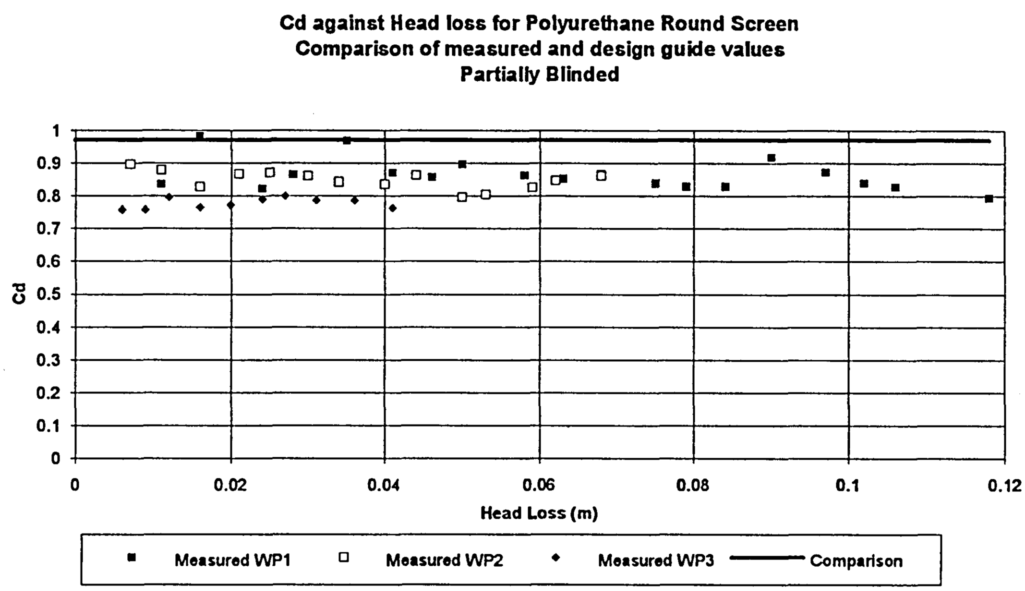


Figure 5.43

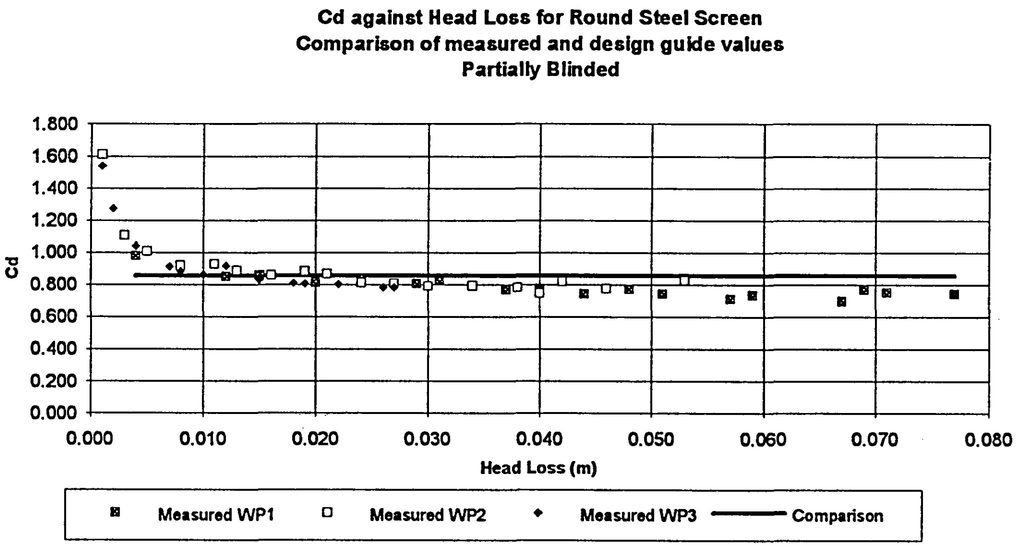


Figure 5.44

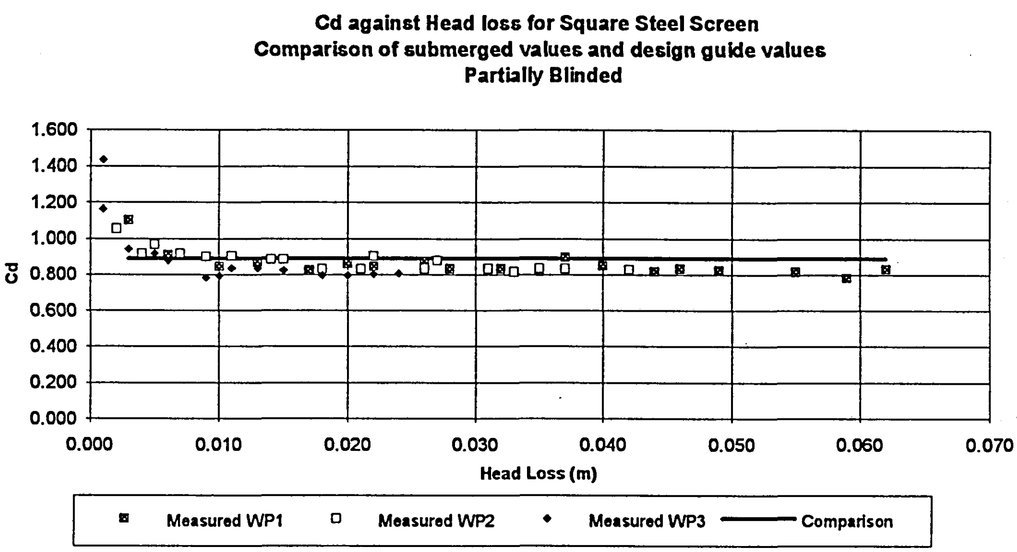
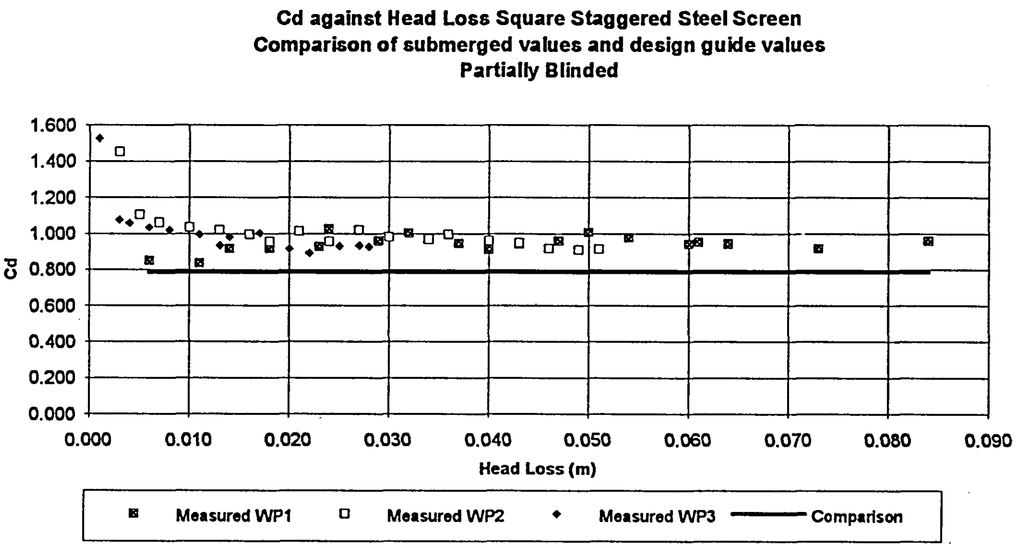


Figure 5.45



Cd against Head Loss Square Staggered Steel Screen
Comparison of submerged values and design guide values
Partially Blinded
1.600
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
Cd
0.000
0.010
0.020
0.030
0.040
0.050
0.060
0.070
0.080
0.090
Head Loss (m)
Measured WP1
Measured WP2
Measured WP3
Comparison

Figure 5.46

12" Flume Laboratory Tests

Relationship between C_d and Head Loss

Screen Mesh Clean

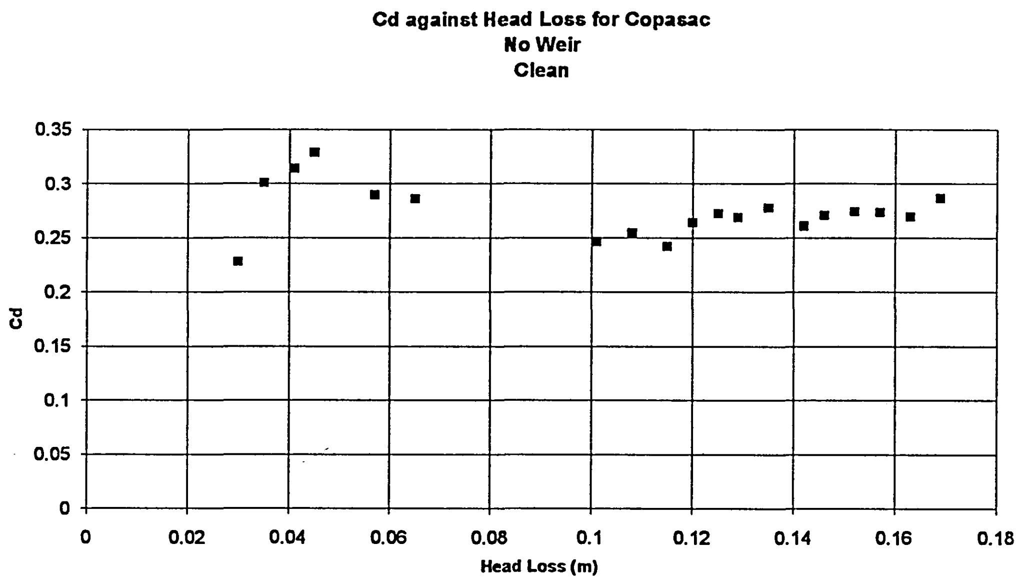


Figure 5.47

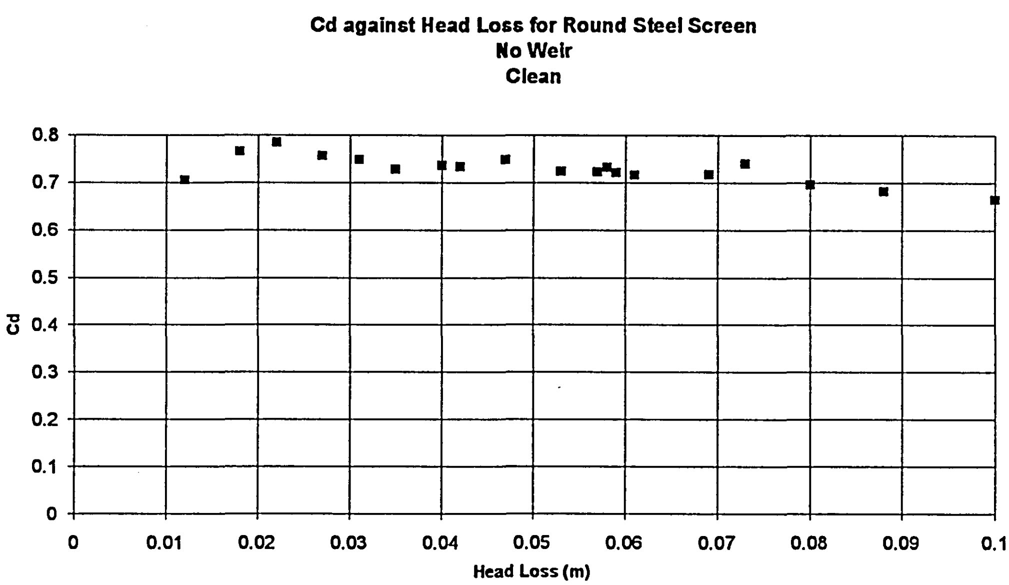


Figure 5.48

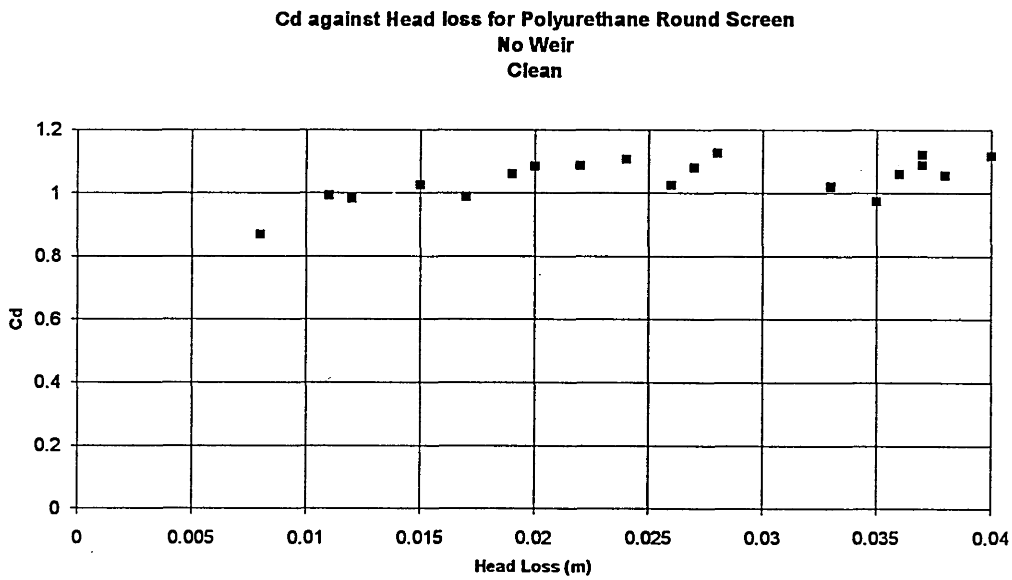


Figure 5.49

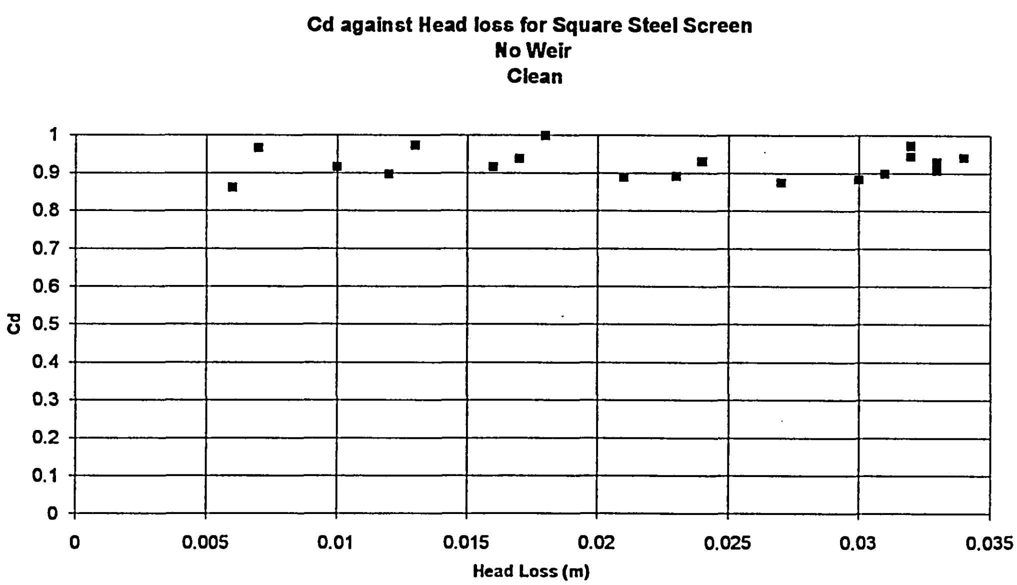


Figure 5.50

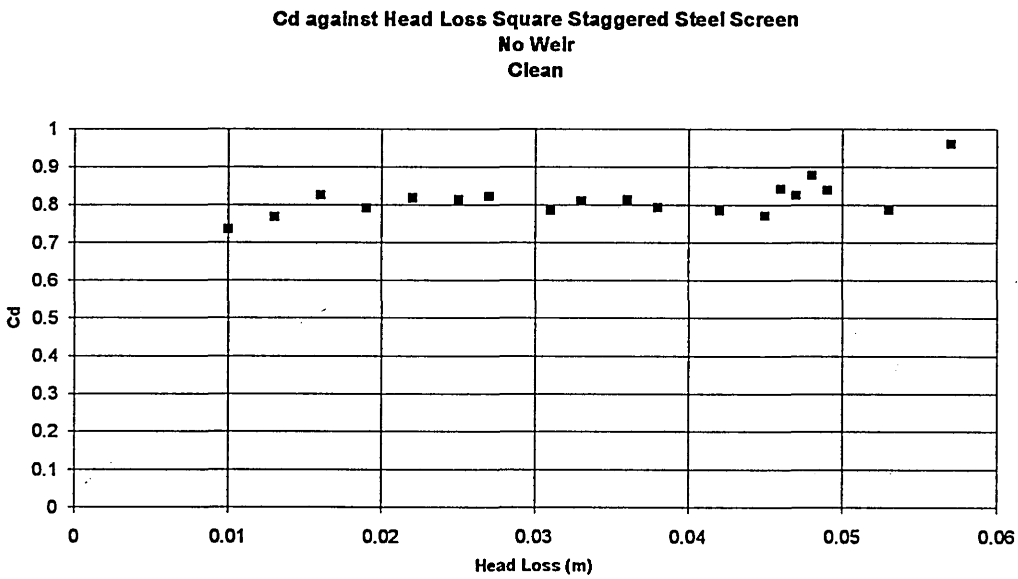

Cd against Head Loss Square Staggered Steel Screen
No Weir
Clean
Cd
Head Loss (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.01
0.02
0.03
0.04
0.05
0.06

Figure 5.51

12" Flume Laboratory Tests

Relationship between C_d and Head Loss

Screen Mesh Partially Blinded

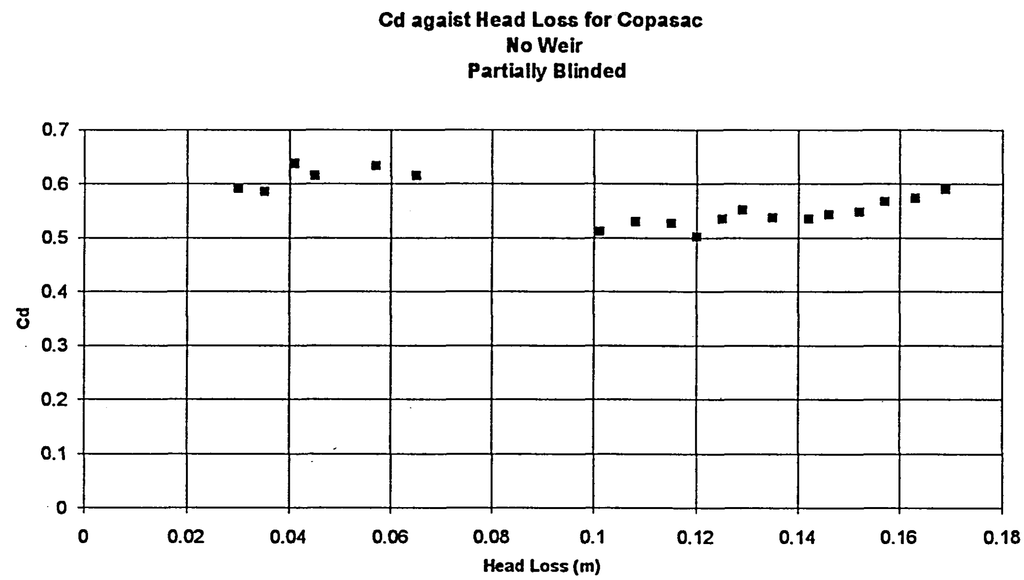


Figure 5.52

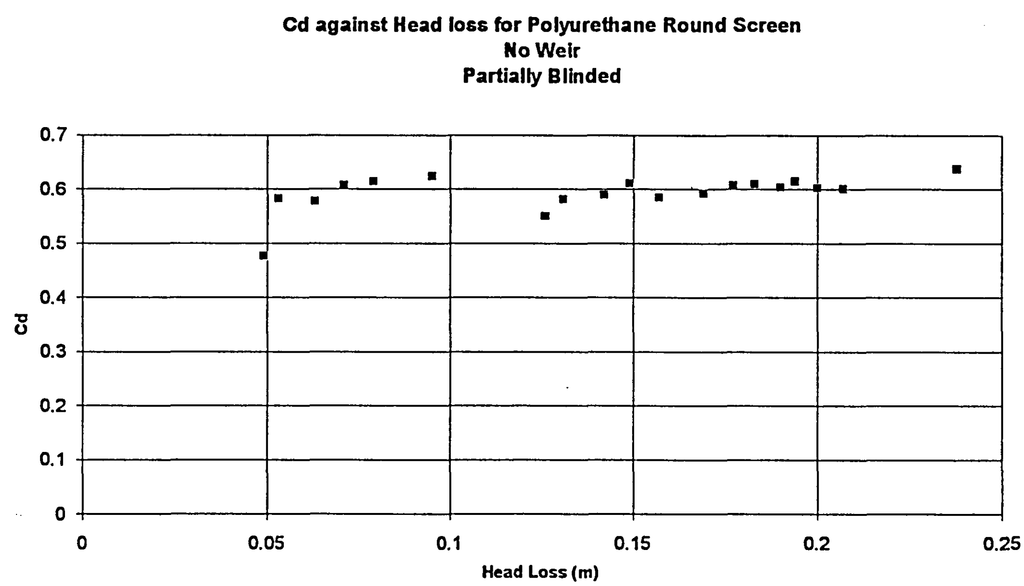


Figure 5.53

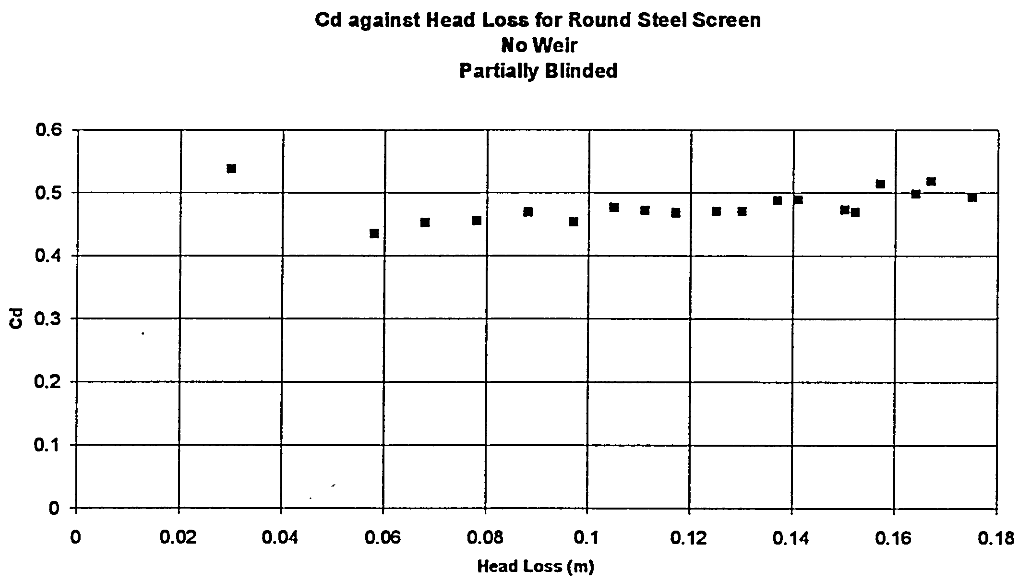


figure 5.54

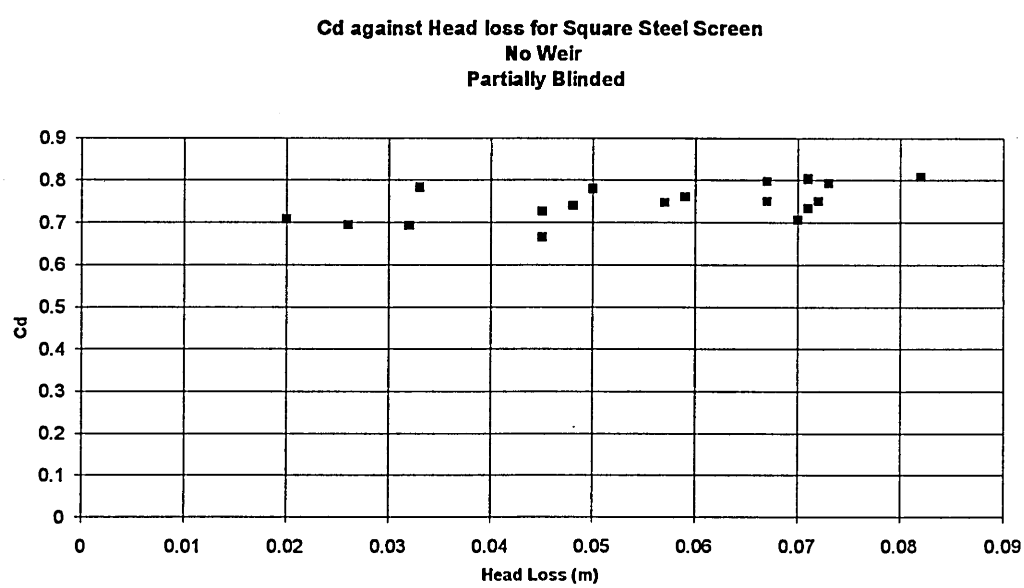


Figure 5.55

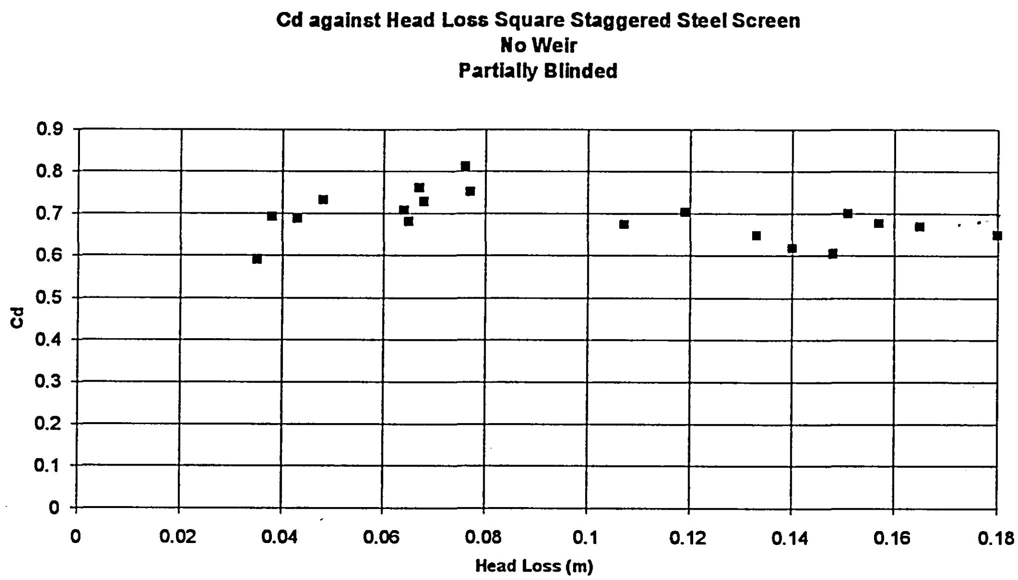

Cd against Head Loss Square Staggered Steel Screen
No Weir
Partially Blinded
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Cd
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
Head Loss (m)

Figure 5.56

CHAPTER 6 DERIVATION OF A PREDICTIVE MODEL FOR MASS OF GROSS SOLIDS PRESENTED TO SCREEN

6.1 Introduction

The work carried out in chapter 3 showed that there appeared to be a trend between the total gross solids mass presented to the CSO screens and the mean overflow intensity. However, when the data from both CSO sites was plotted onto one graph the relationship between the two sets of data was not clear, figure 6.1. A method of translating the data into a dimensionless form needed to be found to enable a clearer relationship to be defined.

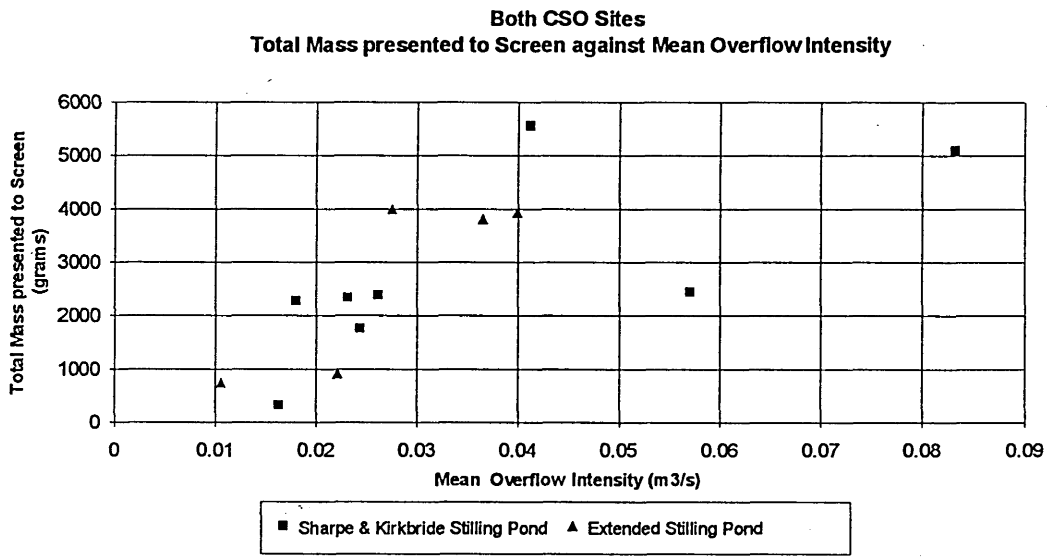


Figure 6.1 Total Mass presented to Screen against Mean Overflow Intensity

The parameters which may influence the mass of gross solids were examined for the two CSO sites. The main materials found to be retained on the CSO screens and passed by the CSO screens were also studied to assess their origin. The main polluting gross solids and their origins are shown in table 6.1

Table 6.1 Main Materials retained and passed by CSO Screens and their origin

Material	Origin
Fine Paper	Dry Weather Flow
Paper Towels	
Sanitary Towels	
Tampons	
Leaves	Storm origin
Sweet Wrappers	

It can be seen from table 6.1 that the main polluting gross solids were of dry weather flow (DWF) origin. It was concluded therefore that the amount of gross solids presented to the screen was a proportion of the DWF gross solids concentration. The DWF is equal to the DWF velocity times the cross sectional area of DWF, i.e.

$$DWF = A_{DWF} \times V_{DWF} \qquad (6.1)$$

Where A_{DWF} = cross sectional area of flow

V_{DWF} = DWF Velocity

$$V_{DWF} \cong \frac{L}{t_c} \qquad (6.2)$$

Where L = length of main branch in catchment

t_c = time of concentration from head of catchment to CSO

Combining 6.1 and 6.2 gives:

$$DWF = A_{DWF} \times \frac{L}{t_c} \qquad (6.3)$$

Rearranging 6.3

$$DWF \times t_c = A_{DWF} \times L \qquad (6.4)$$

The volume of DWF within the system at any one instant is equal to $A_{DWF} \times L$. It was assumed that the mass of gross solids arriving at the CSO chamber during a storm event was dependent on the volume of DWF contained within the catchment before the storm event and the concentration of gross solids in the DWF. So the mass of gross solids presented to the screen was a proportion of the mass of gross solids entering the CSO chamber. The mass of gross solids presented to the screen during a storm event could therefore be represented as a proportion of the total mass of gross solids arriving at the CSO chamber by dividing by DWF x t_c.

The mean overflow intensity of a storm event is defined as:

$$\text{Mean Overflow Intensity} = \frac{\text{Total Volume Spilt}}{\text{Duration of Spill}} \qquad (6.5)$$

Each part of the expression is made dimensionless.

So Total Volume Spilt becomes:

$$\frac{\text{Total Volume Spilt}}{\text{Dry Weather Flow Volume}}$$

$$= \frac{\text{Total Volume Spilt}}{\text{DWF} \times t_c}$$

And Duration of Spill becomes:

$$\frac{\text{Duration of Spill}}{t_c}$$

Hence, Mean Overflow Intensity is made dimensionless by dividing by DWF:

$$= \frac{\text{Mean Overflow Intensity}}{\text{DWF}} \qquad (6.6)$$

Mean overflow intensity can therefore be made dimensionless by dividing by the DWF for each CSO site. Dry weather periods were examined for both CSO sites and a range of values of DWF at differing times of the day and from different months of the monitoring periods were obtained from the raw data files. The mean value of DWF for each CSO site was then calculated from this set of values. The mean dry weather flow was found to be 6.6 l/s for the Sharpe and Kirkbride stilling pond and 18.7 l/s for the Extended stilling pond. The time of concentration is defined as the time taken for the flow to reach the point under consideration from all parts of the catchment. It is equal to the time of entry plus the time of flow. The time of flow is defined as the time taken for the flow to reach the point under consideration from the head of the sewerage system. The time of concentration for each site was assumed to be equal to the time of flow within the catchment area. Figure 6.1 was then re-plotted using the dimensionless parameters to allow for the differences in the two catchments, this plot is shown in figure 6.2.

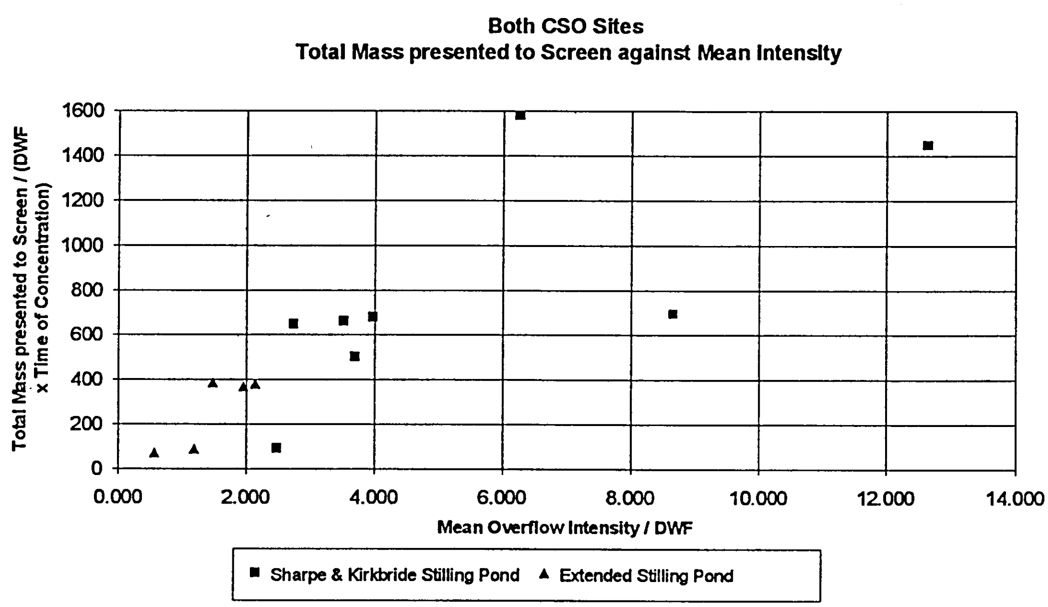


Figure 6.2 Total Mass Presented to Screen against Mean Overflow Intensity (Dimensionless)

A predictive model of the mass presented to the screen was then produced and the results were plotted onto figure 6.2. The predictive model is discussed in section 6.2.

6.2 Theory

The occurrence of a first foul flush effect has been widely reported (Hedley and King, 1971; Saul and Thornton, 1989; Cootes, 1990; Lonsdale, 1994). The magnitude of the polluting load is thought to be related to the peak storm intensity, the duration of the storm, the time of concentration and the antecedent dry weather period (ADWP)

(Hedley and King, 1971; Saul and Thornton, 1989). Hedley and King, 1971, discovered that 90% of the pollutants could be expected to arrive at the overflow before the peak of the hydrograph for intense storms. Cootes, 1990, found several recorded storms indicated a first foul flush with a peak level of pollutant concentrations at the beginning of the storm, coinciding with, and sometimes preceding, the peak inflow rate. Lonsdale, 1994, observed the first foul flush effect at two of the four CSO sites investigated. The pollutant load for a significant number of storms was found to tail off in advance of the inflow peak. The general approach to calculating the storage volume for a particular storm hydrograph (Hedley and King, 1971) is given in figure 6.3.

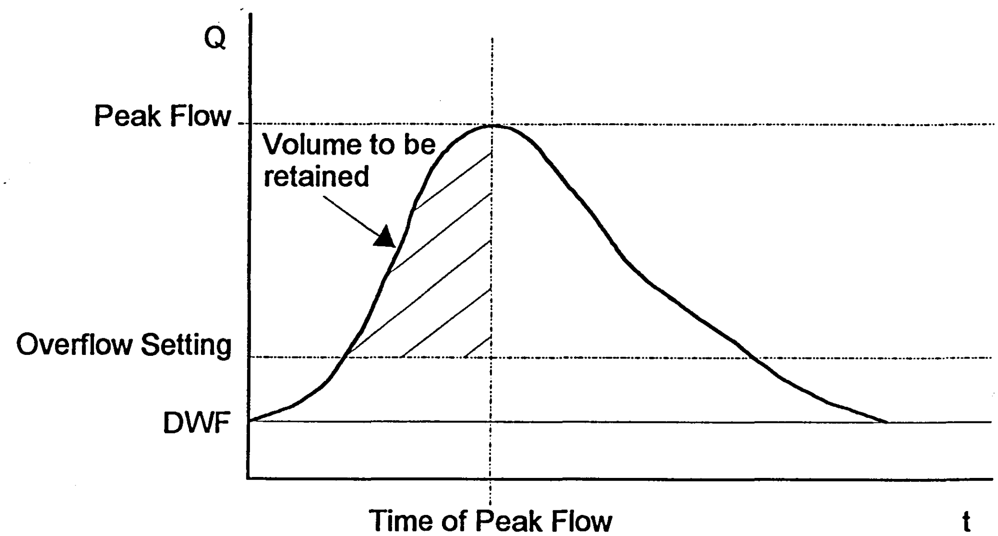


Figure 6.3 Inflow hydrograph showing storage volume (Hedley & King, 1971)

The volume to be retained is the volume which Hedley and King suggested storage should be provided for. The volume above the overflow setting is the volume which without storage is split to the nearest watercourse. The volume to be retained is the volume spilt up to the peak of the hydrograph which as research as shown (Hedley & King, 1971) contains the highest polluting load. It was assumed, therefore, when building a model for predicting the mass of gross solids presented to the CSO screen that all of the mass of gross solids would have arrived at the CSO chamber by the peak inflow. The volume up to the peak inflow was calculated for each inflow hydrograph relating to a gross solids sample by calculating the volume under the curve for each time step and deducting the volume below the overflow setting which would be carried forward to treatment, figure 6.4.

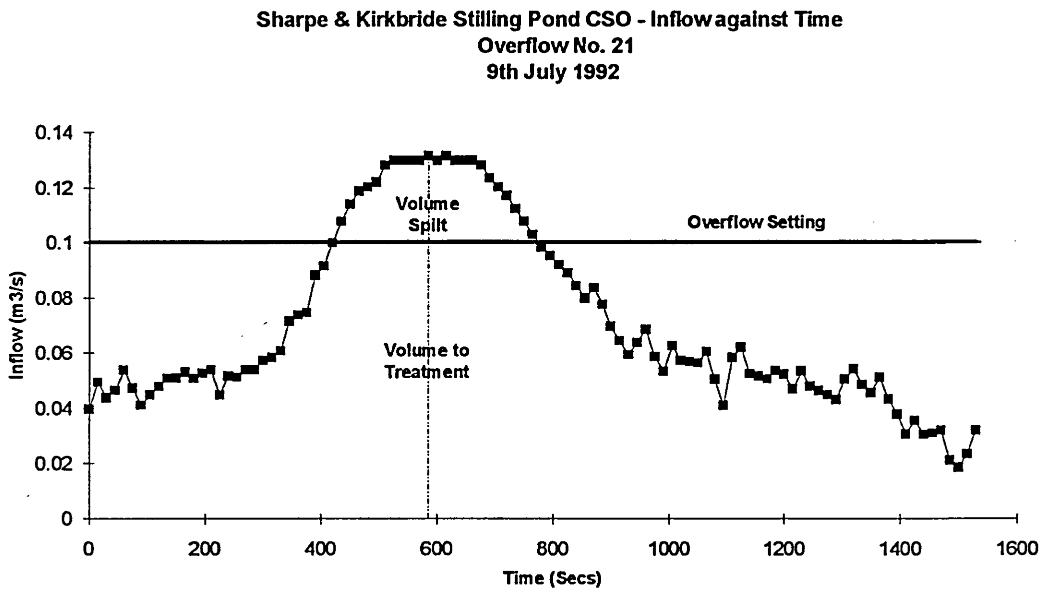


Figure 6.4 Inflow Hydrograph; Sharpe & Kirkbride Stilling Pond CSO

Where gross solids samples represented one or more storm events the dates and times of the overflows were examined to assess whether the system would have had time to return to DWF and thus present further gross solids to the CSO screens during a subsequent storm event. Table 6.2 lists the dates and times of the storm events for the two CSO sites. Where a gross solids sample represented multiple storms, the volume of any subsequent storm events was included in the volume calculated for the first storm event. This was only done if the time between the storm events was sufficient to allow the dry weather flow volume to build up again. For example, sample 7 for the Sharpe & Kirkbride stilling pond was collected on 13th July 1992 and represented overflows 21, 22, 23 and 24. Examining the dates and times of these overflows shows that overflow 21 occurred on 9th July 1992 and the other three overflows occurred on 11th July 1992 in short succession. The volume up to peak was therefore calculated for overflows 21 and 22.

Table 6.2 Dates and Times of Storm Events resulting in Overflow

Sharpe & Kirkbride Stilling Pond				
Date	Time		Overflow No.	Gross Solids Sample No.
	From	To		
29/3/92	16.44	16.56	3	1
8/6/92	16.16	17.02	16	4
8/6/92	19.10	19.24	17	
1/7/92	6.27	6.46	18	5
3/7/92	11.22	14.17	19	6
4/7/92	6.04	6.23	20	
9/7/92	10.16	10.24	21	7
11/7/92	18.40	18.54	22	
11/7/92	19.56	20.16	23	
11/7/92	23.12	23.30	24	
12/8/92	5.48	5.53	30	8
12/8/92	9.52	10.00	31	
21/9/92	19.04	19.17	33	9
21/9/92	21.52	22.45	34	
26/9/92	0.19	1.23	35	10
Extended Stilling Pond				
Date	Time		Overflow No.	Gross Solids Sample No.
	From	To		
27/10/92	8.42	9.30	2	1
9/11/92	19.07	19.24	3	2
11/11/92	3.12	3.30	4	
11/11/92	6.32	7.20	5	
21/11/92	15.30	16.42	7	3
30/11/92	10.50	11.38	9	4
5/12/92	0.14	0.25	11	5

The concentration of gross solids /m^3 should be similar for the two CSO sites if the personal habits of the population of the two catchments is similar. The gross solids concentration was assessed by establishing the weight of gross solids per person per day which enter the system. The market research department of Boots The Chemist, Nottingham were contacted to find out if they had carried out any market research to discover typical figures for the usage of sanitary products. A survey had been carried out by Boots in conjunction with Company magazine in October 1993 after the launch of Always sanitary towels. The results of the survey shown below were obtained during a telephone conversation with the market research department. There were 1009 respondents and the survey found that the number of products used by women each month were:

Product	Number per Month
Press-on Towels	24
Panty Liners	9
Panty Liners used at other times of month	11
Applicator Tampons	23
Non-applicator Tampons	21

The percentage of women using each product were

Product	%
Press-on Towels	23
Towels with Belt	1
Panty Liners	34
Applicator Tampons	57
Non-applicator Tampons	31

Some women used more than one product each month. The average length of menstruation was 5 days and 68% of women were found to have a 28 day cycle, 10% < 28 day cycle and 22% > 28 day cycle. The mean wet weight of these products was then found

Material	Grams
Press-on Sanitary Towels	75.7
Press-on Mini Towels	41.9
Panty Liners	17.2
Applicator Tampons	19.4
Non-applicator Tampons	22.2

The mean wet weight per person of the other materials of dry weather flow was also established. The amounts of male and female toilet tissue were decided upon after consultation with colleagues.

Material	Grams
Male Toilet Tissue	40.6
Female Toilet Tissue	94.5
Paper Towel	17.1

The total mass of gross solids entering the catchment each day was then found by assuming there were 2.7 people per house with 1 female per house, menstruating for 5 days out of every 28. Each house was assumed to be 50% male and 50% female and paper towels were assumed to account for 5% of the number of houses. The DWF was calculated in litres per day using:

DWF =(population x 250 l per person per day)

+ (infiltration 0.05 l per sec per hectare)

+ (industrial effluent, if any)

The DWF gross solids concentration for each CSO site was then expressed in grams per litre and was found to be 0.25 g/l for both catchments.

The volume of DWF in the system at any one instant was determined by producing a WALLRUS (Hydraulics Research, 1989) model of each catchment area. A measured storm was set up with zero intensities and the catchment was then run to obtain the volume of DWF in the system from the listing file.

The mass of gross solids in the system was then determined by multiplying the DWF gross solids concentration (g/l) by the volume of DWF in the system at any one instant. The mass of solids presented to the CSO screen is then found by determining the volume split proportion, figure 6.5, and multiplying it by the mass of solids in the system when the storm commences.

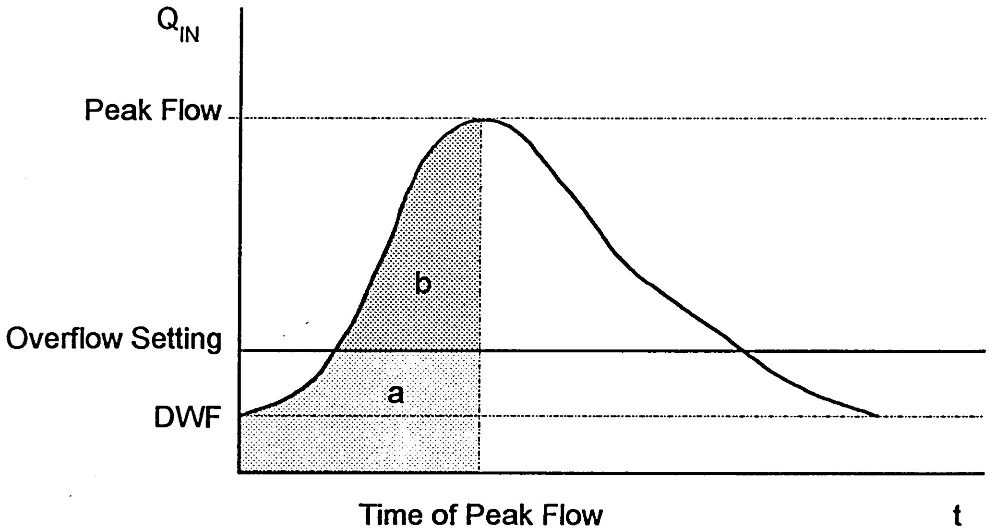


Figure 6.5 Inflow hydrograph illustrating volume split

Area a = Volume to treatment

Area b = Volume spilt

Area a + b = Volume entering CSO chamber

$$\text{Flow split} = \frac{b}{a + b} \qquad (6.9)$$

6.3 Results

The mass presented to the CSO screens was predicted for each relevant storm event and these were plotted onto figure 6.2 for comparison. The results are shown in figure 6.6. A straight line was then drawn by eye through the set of points the result can be seen in figure 6.7. Figure 6.8 shows a plot of the measured mass against the predicted mass and the least squares line for the data. The gradient of the line was found to be nearly 1 indicating that the model correlates well with the theory

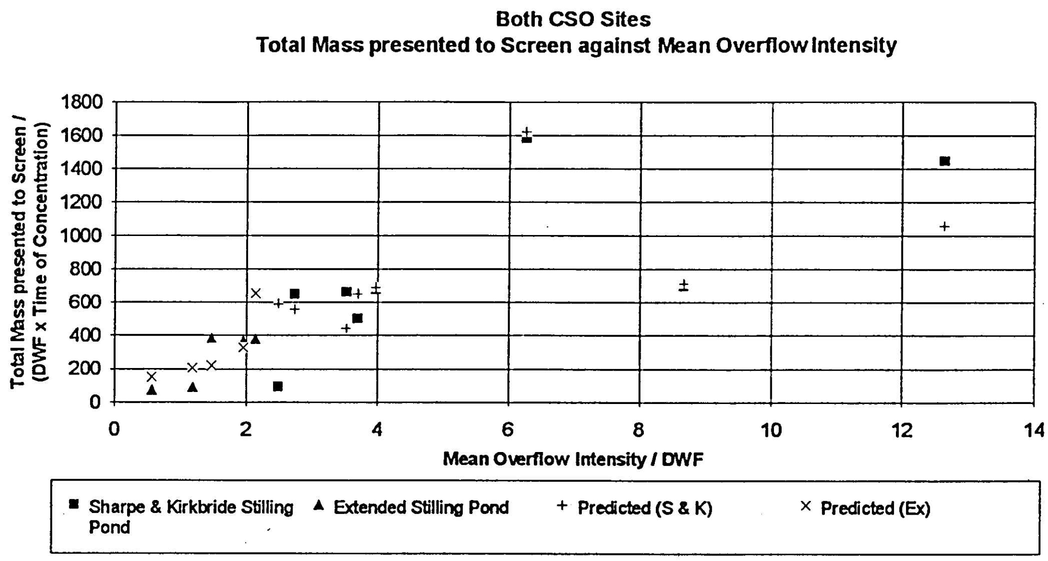


Figure 6.6 Measured and Predicted Mass presented to Screen against Mean Overflow Intensity

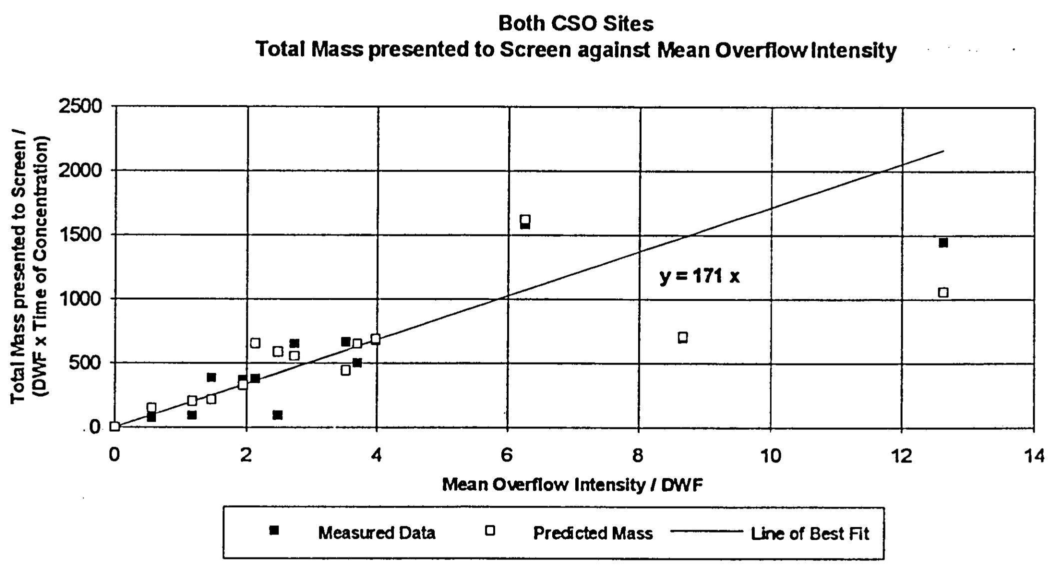


Figure 6.7 Line of Best Fit for Predicted Data

Plot of Measured Mass against Predicted Mass

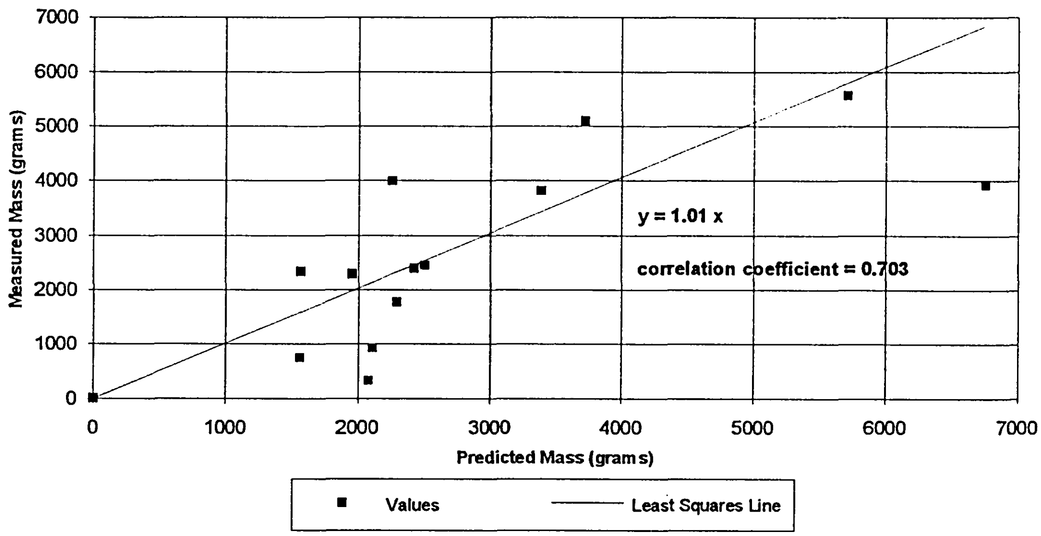


Figure 6.8

6.4 Discussion

The results have shown that the predictive model compares well with measured values and the mass presented to the CSO screens can be reliably predicted. However, as can be seen from the results some scatter of points does exist. Figure 6.9 shows the banding of the data points is ± 48%. One explanation for this could be the time of day that the storm occurred and the diurnal variations in the dry weather flow. For example, the gross solids sample 10 for the Sharpe and Kirkbride stilling pond occurred between 0.19 a.m. and 1.23 a.m. when the DWF would be near a minimum. Consequently the mass of gross solids would be lower than a storm which occurs during peak DWF. The results have indicated that the mass of gross solids lie at the lower boundary of the scatter of points. Conversely, sample 4 for the Sharpe and Kirkbride stilling pond occurred between 19.10 p.m. and 19.24 p.m. when the DWF would be near a peak. The results have indicated that the mass of gross solids for sample 4 lie at the upper boundary of the scatter of points. The points which are well within the upper and lower boundaries and lie close to the line of best fit have been found to have storm events times which are neither in a DWF trough or a DWF peak but somewhere in between. These storm events have therefore produced average gross solids masses. For example, samples 2 and 4 for the Extended stilling pond were found to have storm events which occurred between 6.32 a.m. to 7.20 a.m. and 10.50 a.m. to 11.38 a.m. respectively.

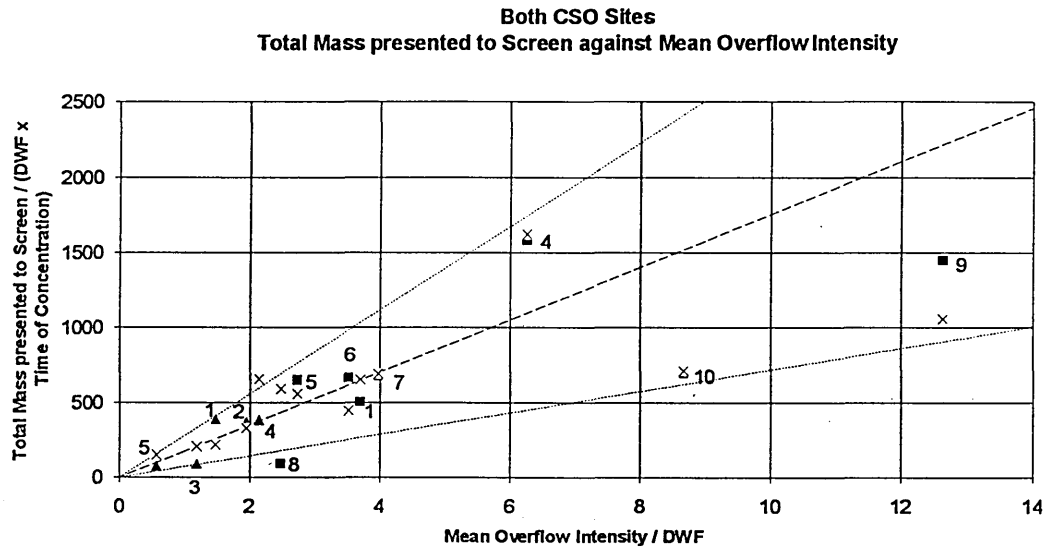


Figure 6.9

Differences in the shape of the inflow hydrographs may also account for the horizontal drift of some of the data points. Figures 6.10 and 6.11 show typical inflow hydrographs for the Sharpe and Kirkbride stilling pond. Figures 6.12 and 6.13 give the inflow hydrographs for the storm events which resulted in samples 4 and 10 for the Sharpe and Kirkbride stilling pond. Comparison between these four figures illustrates the differing shapes of the latter two. There was a sudden increase in the flowrate entering the chamber for overflow 16, figure 6.12, instead of the gradual increase seen for overflows 30 and 33, figures 6.10 and 6.11. Overflow 35, figure 6.13, spills for over half an hour at a steady flowrate before there is a sudden increase in the inflow. Overflows 16 and 35 also had much longer duration's of spill compared to the other storm events. The gross solids samples relating to overflows 16, 30 and 33 came from multiple storm events, sample 10 came from overflow 35. The samples which lie on the upper and lower boundaries of the scatter of points were found to be from multiple and single storm events showing the results were not influenced by the multiple storms. The results for the predictive model have shown that the method used for analysing multiple storms was appropriate.

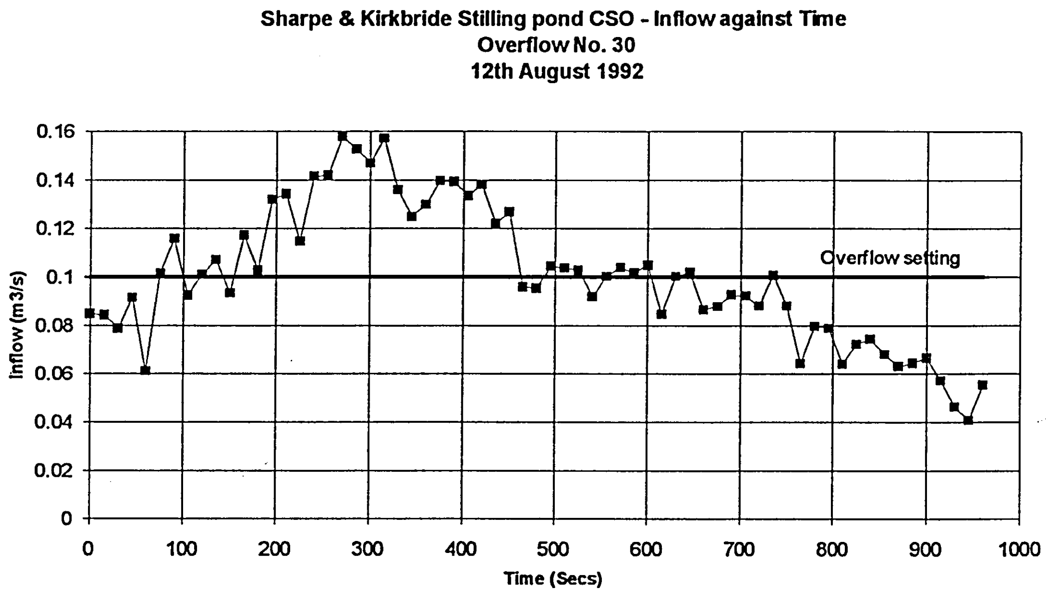


Figure 6.10

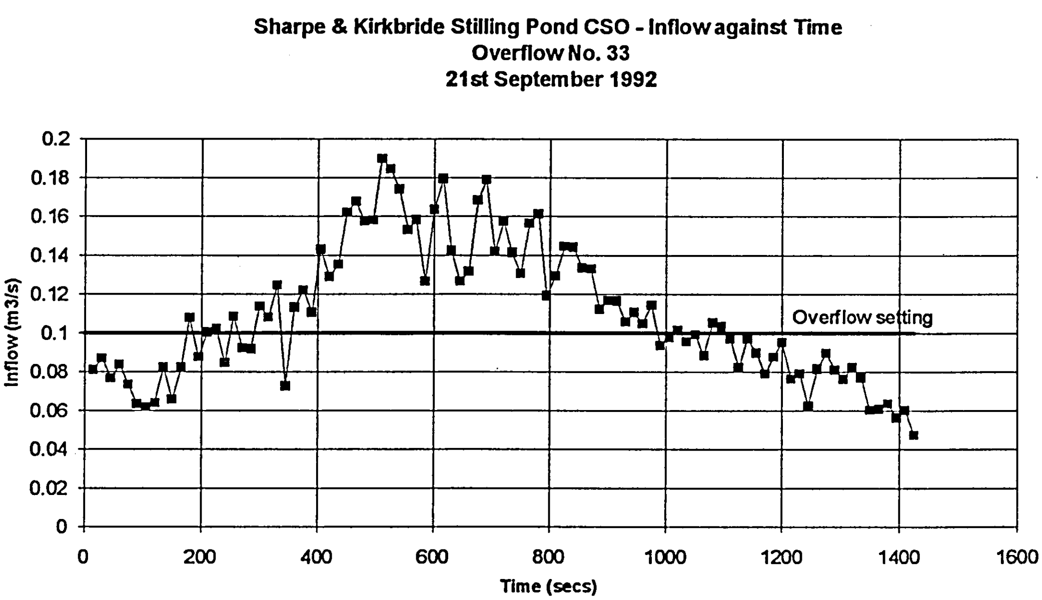


Figure 6.11

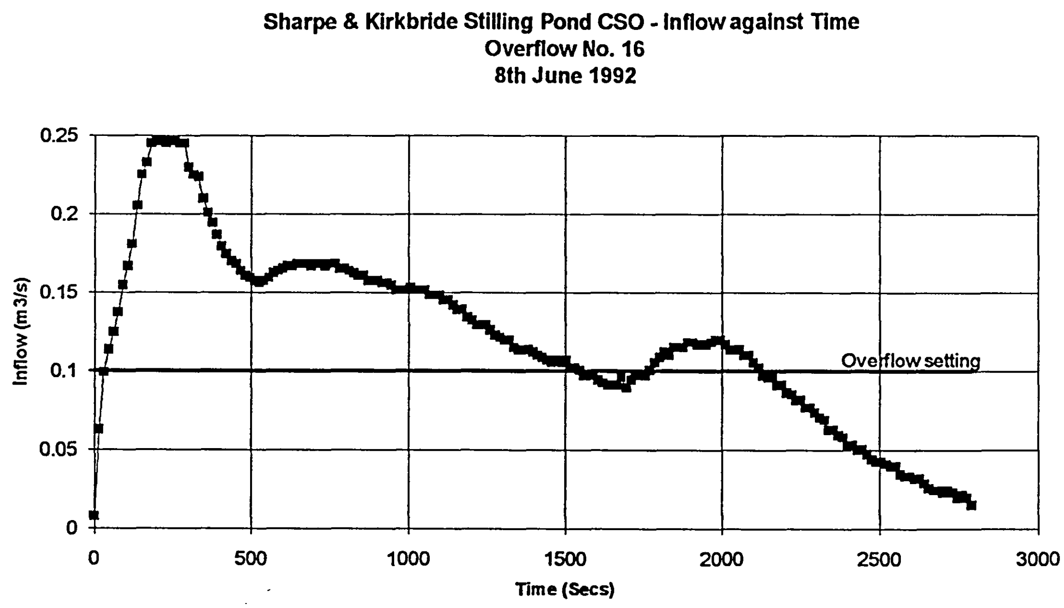


Figure 6.12

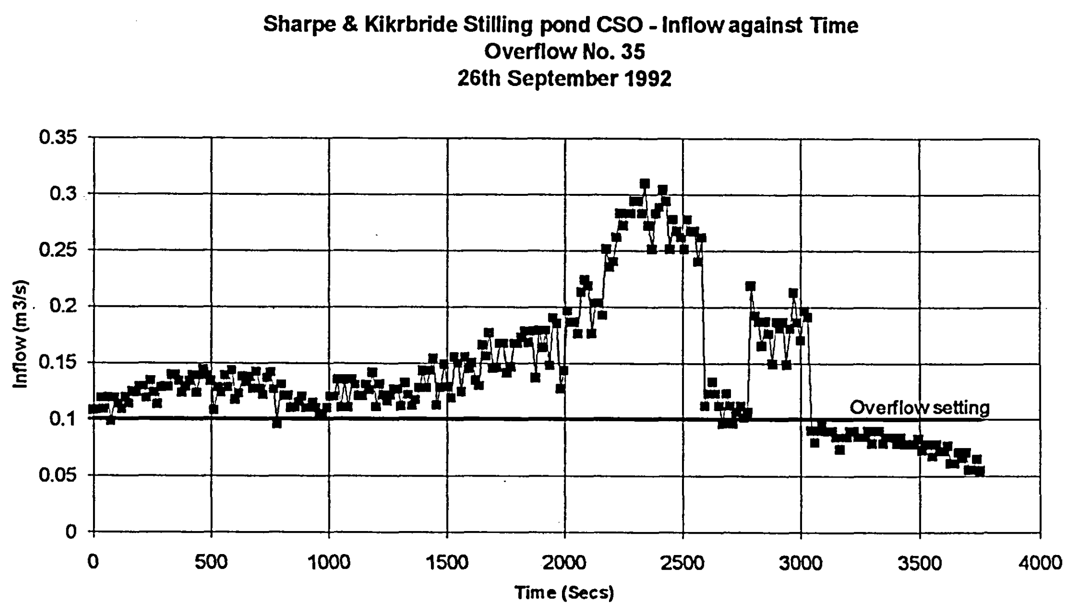


Figure 6.13

CHAPTER 7 DISCUSSION

Overall Screen Efficiency: It has been found that the screens tested had low gross solids retention efficiencies. Table 7.1 shows a comparison of the mean screen retention efficiencies of all the screens tested. It should be remembered that the comparison can be misleading because the bar screen tests were carried out on actual screen installations, whereas the mesh screen tests were only carried out on the screen meshes. Therefore, the mean screen retention efficiencies quoted for the bar screens are the actual efficiencies of the screen installations, whereas the efficiencies quoted for the mesh screens are the highest screen retention efficiencies possible for the screening media. Other factors influence the retention efficiency of a screen installation. For example, inefficient cleaning of the screen face will cause carry over and pass through of gross solids, and poor seals will allow gross solids to by-pass the screen.

Table 7.1 Comparison of Mean Screen Retention Efficiencies

Screen	Mean Screen Retention Efficiency (%)
25 mm STW D-screen	10
15 mm D-screen Extended stilling pond	18.5
15 mm D-screen Sharpe and Kirkbride stilling pond	20
6 mm STW inclined bar screen	29
6 mm mesh tests at Holbrook STW	51
6 mm mesh tests in Laboratory	55
6 mm mesh tests at Long Lane STW	60

The results show that the size of the screen face apertures affects the screen retention efficiency. The smaller the aperture the higher the screen retention efficiency. Figure 7.1 shows the relationship between bar screen spacing and screen retention efficiency. There is a high correlation which shows that as the bar spacing decreases the screen retention efficiency increases, figure 7.1. However, further work should be done on a range of bar screen spacings to investigate the relationship further. The straight line relationship could be misleading as the bar screens tested represented a narrow band of bar spacings and with additional points plotted from a wider range of sizes the relationship may not be linear.

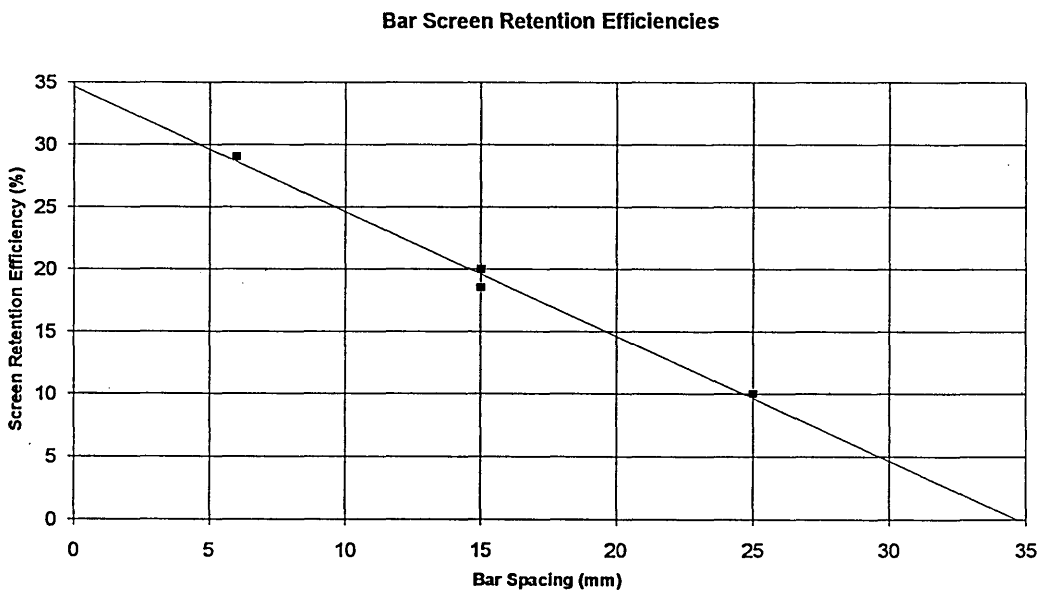


Figure 7.1 Relationship between bar spacing and screen retention efficiency

The mean efficiencies in table 7.1 mask the wide range of efficiencies of a particular screen for different types of gross solids. The two main materials which have been found to pass through the screen meshes were fine paper and cotton bud sticks. These materials will still cause aesthetic pollution when discharged to receiving watercourses. However, it may be that the discharge of these materials may be acceptable in meeting the current guidelines (NRA, 1993). The low screen retention efficiencies may also be acceptable if, for instance, a CSO chamber marginally fails to meet the required criteria. By fitting screens it is possible to enhance the performance of a CSO chamber and this may be more practical and cost effective than achieving the same performance through storage. For example, if 40% of the flow entering a basic CSO chamber is spilt and 60% of the flow entering the chamber is passed forward to treatment then 40% of the gross solids entering the CSO will be passed over the weir. If the same CSO chamber is fitted with a 15 mm bar screen which has a screen retention efficiency of 20%, then 20% of the gross solids passing over the weir will be retained. This equates to a further 8% of the gross solids entering the CSO chamber being passed forward to treatment. Figure 7.2 is a diagrammatic representation of a CSO chamber with a flow split of 60% fitted with a 15 mm bar screen having a screen retention efficiency of 20%.

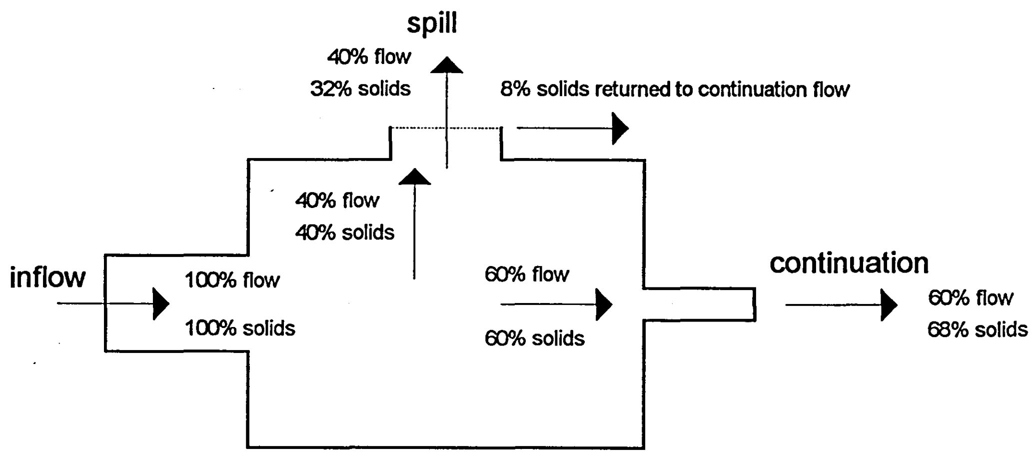


Figure 7.2 CSO chamber fitted with screens

CSO Screen Design: The design of CSO screens should be as simple as possible. The more complex a screen becomes the greater the chance of screen failure. Screen failure may result in a higher mass of gross solids being discharged to the receiving watercourse, or upstream surcharging and flooding of the sewerage system. This may then result in upstream CSOs operating prematurely thus increasing the pollutant load to the watercourse still further.

Raking: The design of the raking mechanism is just as important as the design of the actual screen. The use of front raking mechanisms may reduce the overall screen efficiency by the insertion of the rake into collected screenings from the front forcing some screenings through the bars. Material not deposited by the rake can also be re-introduced into the pre-screened sewage becoming more comminuted and eventually passing through the screen. A continuous back raking mechanism like the inclined bar screen at Long Lane sewage treatment works lifts the accumulated screenings by the rakes passing through the screen bars from the downstream side of the screens. However, if the screenings are not all removed from the rakes at the top of the raking cycle, the material is introduced into the screened sewage. Raking mechanisms must also be regularly maintained. The raking mechanism for the D-screen at Long Lane sewage treatment works may once have worked efficiently but as the mechanism has worn with time the bar designed to push the screenings off the rake when it reaches the top of its cycle no longer meets the rake and only when there has been a massive build up of material on the rake are the screenings deposited onto the conveyor belt. In order to obtain results for the coarse screen during testing the rakes had to be manually cleaned, otherwise the screen would have had a continual zero efficiency with an occasional high efficiency resulting from a large gross solids sample being deposited on the conveyor belt.

The speed and mechanism of raking clearly influences screen retention efficiency. Observations of the front raking mechanism of the D-screen at Long Lane STW showed that the insertion of the raking tines into the collected gross solids forced some of the gross solids through the bars. Some of the gross solids were also comminuted by the action of the raking mechanism. The back raked inclined bar screen at Long Lane STW was observed to lift the retained gross solids up the screen face without comminution and without forcing them through the screen bars. The rate of raking influences the rate of blinding which in turn influences screen retention efficiency and it is likely that a relationship exists between these parameters. However, establishing such a relationship was beyond the scope of the work and further work should be done in this area.

Grit Separation: Consideration must be given to grit separation when installing screens in combined sewer overflows. Sedimentation upstream of the screen could prevent the raking mechanism from operating correctly. Improved overflow chamber design could help to reduce this but grit problems in a site with a history of sedimentation need to be addressed prior to an inclined screen installation. When grit is present the screen will not work as efficiently due to the increased work load. Low velocities of flow in the approach channel to a screen should be avoided. Precautions should be taken to remove grit from the flow or to ensure that the screen installation is capable of handling grit deposition. Experience at Long Lane STW has shown that sedimentation infront of the inclined bar screen was caused by the large screening area and low velocities of flow upstream of the screen. This grit deposition was responsible for mechanical failure of the screen.

Plastic Mesh Sacks: Copasacs could be used in a similar way to the spill sample collection, effectively as a secondary screening device installed across the spill chamber or overflow pipe. The only disadvantage of using Copasacs is the high maintenance required as regular inspections would need to be carried out and the Copasacs changed and disposed of after each storm event. Particularly environmentally sensitive situations would benefit from the use of Copasacs where high maintenance requirements may be offset against the environmental sensitivity of the receiving watercourse.

Screening in Series: Installing coarse and fine screens in series may reduce the work load of the finer screen enabling it to operate more efficiently. Laboratory observations have shown that gross solids tend to be turned on end upstream of a screen and are passed through the screen apertures. By placing screens in series turbulence is created which would tend to make the approach pattern to the second finer screen more random and that in turn would make the screen more efficient.

Bar Screens: Bar screens have been found to pass material with two dimensions larger than the bar spacing. The 6 mm solids separation criteria as defined by the regulators in the current guidelines (NRA, December 1993) which states that there shall be separation, from the effluent, of a significant quantity of persistent material and faecal/organic solids greater than 6 mm in any two dimensions, is therefore unattainable with a 6 mm bar screen. In order to achieve the 6 mm solids separation criteria a 6 mm mesh screen or a bar screen with a spacing less than 6 mm will be required. As the spacing between bars becomes smaller, the size of the bar is also reduced to maintain the open area of the screen. It was found with the inclined bar screen at Long Lane STW that over a period of time the bars had been forced apart by both the flow and the material retained by the screen. The 6 mm spacing was only maintained where the raking tines were passing through the screen. The screen bars effectively spanned between the raking tines which meant that objects larger than 6 mm in three dimensions could be forced through the gaps by the pressure of the upstream head.

Mesh Screens: Mesh screens are much harder to clean than bar screens and most require some form of washwater. It was found from the screen mesh tests that manual cleaning of the screens was extremely difficult. Installation of this type of screen on a CSO is not recommended without an automatic cleaning system. The head losses measured during the screen mesh tests at the STWs indicate that this must be allowed for in the CSO design. In addition to this the screening mesh must be able to withstand the flow passing through it without buckling or failure which has been a fault associated with some screens (Thompson et al, 1993).

Gross solids: It has been found that the major polluting gross solids are of dry weather flow origin. One of the main public complaints is of condoms and sanitary products hanging from vegetation and deposited along river banks. Only seven condoms were found during the whole of the CSO monitoring period and they were only collected in 1 in 12 samples at the STWs. This would indicate that the incidence of condoms found along watercourses may not be of sewage origin. However, the seven condoms which were all found at the Sharpe & Kirkbride stilling pond CSO were not retained by the D-screen and would have therefore been discharged to the River Sheaf. Of the identifiable sanitary towels collected at the CSO sites at least three quarters of all those presented to the screens were retained and they represented 15% of the total sample mass which equates to approximately 422 grams. The average wet weight of a clean sanitary towel has been found to be 67 grams. The total sample mass of sanitary towels therefore represents approximately 6.3 towels of which three quarters (4.7 towels) are retained. The number of sanitary towels discharged to the watercourse during each storm event therefore is only 1.6. Similarly, at least 85% of all tampons presented to the CSO screens are retained and they only represent 2% of the total sample mass. This equates to approximately 55 grams. The average wet weight of a clean tampon has been found to be 18 grams. The total sample mass of identifiable tampons therefore represents approximately 3.1 tampons of which at least 85% (2.6 tampons) are retained. Only 0.5 tampons are discharged to the watercourse during each storm event. The remainder of the sanitary products which are discharged into the sewerage system become shredded within the system and arrive at the CSO chamber as fine paper material. Table 7.2 shows the mean material composition for all the sites investigated together with the laboratory tests. It can be seen that there was a much higher percentage of fine paper at the STW sites when compared to the CSO sites. It can also be seen that the percentage of fine paper material used for the laboratory tests was more comparable to the CSO sites. The mean sample masses for the CSO sites and the STW sites are given in table 7.3. The mean sample mass collected at the CSO sites is more than double the mean sample mass collected at the STW sites and in some cases three times the mean sample mass of the STW sites.

The bulk of gross solids arriving at a CSO chamber during a storm event arises from the DWF stored in the sewerage system prior to the storm event. The mass of gross solids presented to a CSO screen during a storm event or passing over the overflow weir where no screens are present can be predicted using the CSO inflow hydrograph and the dry weather flow gross solids concentration. The DWF gross solids concentration can be calculated from the population of the catchment and the volume of DWF in the system prior to spill. This is a useful tool for determining the amount of aesthetic pollution likely to arise from a CSO. The mass presented to the screen increases with the mean overflow intensity. Therefore as the mean overflow intensity increases the actual mass being discharged to the watercourse increases. A steep catchment with a high mean overflow intensity will discharge a greater proportion of gross solids to the watercourse than a flatter catchment with a low mean overflow intensity.

The presence of gross solids hanging from vegetation and deposited along river banks are regarded by the public as a clear indication that a watercourse is polluted (Realey, 1992). It can be argued that in terms of public perception preventing the aesthetic pollution of watercourses from CSOs is just as important as reducing the numbers of sewage-derived micro-organisms which are also discharged to watercourses but are unseen. Further work should be carried out on the characteristics of gross solids and their behaviour within the sewerage system to enhance the work already done in this area. Increased public awareness is also required to try to reduce the number of sanitary products and other items which are regularly flushed down the toilet by the public.

Table 7.2 Mean Material Composition of all Testing Sites

Material	Holbrook STW (%)	Long Lane STW (%)	Laboratory Testing (%)	Sharpe & Kirkbride Stilling Pond (%)	Extended Stilling Pond (%)
Condoms	0.0	0.0	1.3	0.1	0.0
C. B. Sticks	0.3	0.3	1.6	0.0	0.0
Fine Paper etc.	96.9	85.1	47.0	51.0	28.2
Sanitary Towels	2.5	10.1	34.3	16.5	15.3
Paper Towels	0.0	0.0	0.0	5.4	4.4
Leaves	0.0	0.0	0.0	10.4	45.4
S. Wrappers	0.0	0.0	0.0	2.4	1.4
Tampons	0.3	4.5	15.8	2.6	2.1
Other	0.0	0.0	0.0	11.6	3.2

Laboratory tests: It has been shown that full scale laboratory tests of screen meshes can predict the screen retention efficiencies likely to be found in the field. However, a different laboratory test needs to be devised to cover the range of head losses found in the field. It must be remembered that experience gained from the field testing was used to simulate the gross solids in the laboratory and without this knowledge it is unlikely that comparable efficiencies would have been achieved.

Table 7.3 Mean Sample Mass

Site	Mean Sample Mass (g)
Sharpe & Kirkbride Stilling Pond	2855
Extended Stilling Pond	2600
Long Lane STW Mesh Screen Tests	960
Holbrook STW Mesh Screen Tests	1085
Long Lane STW Inclined Bar Screen	1781
Long Lane STW D-screen	997

CHAPTER 8 CONCLUSIONS

8.1 CSO screens can retain gross solids and will therefore reduce the aesthetic pollution of watercourses. However, they cannot prevent the discharge of all of the gross solids which pass over the overflow weir. A percentage of the gross solids passing over the weir will reach the watercourse.

8.2 The retention efficiency of screens has been found to be dependent on the aperture size of the screen face. The larger the aperture the screen has the lower the retention efficiency.

8.3 A 6 mm mesh screen will have a higher retention efficiency than a 6 mm bar screen. Bar screens have been found to pass gross solids with two dimensions greater than the bar spacing. Gross solids which are greater than 6 mm in any two dimensions will therefore be passed by a 6 mm bar screen.

8.4 The bulk of the gross solids arriving at a CSO chamber during a storm event arises from the DWF prior to the storm event.

8.5 The mass of gross solids passing over the CSO weir can be reliably predicted from the inflow hydrograph and the dry weather flow gross solids concentration. The dry weather flow concentration can be calculated from the population of the CSO catchment and the volume of DWF stored in the system prior to spill.

8.6 Full scale laboratory tests can predict the screen retention efficiencies likely to be found in the field providing care is taken in the laboratory when simulating the gross solids. The degradation of the gross solids within the sewerage system needs to be closely reproduced to obtain results which are similar to the field environment.

8.7 The main polluting gross solids have been found to be of dry weather flow origin. The incidence of condoms and cotton bud sticks at the two CSOs investigated was small (less than 0.1% of the overall sample mass). At least 75% of all sanitary towels and at least 85% of all tampons were retained by the CSO bar screens. The material which passed through all the screens investigated was fine paper. This material consists of toilet tissue and sanitary towel inners which become finely shredded in the flow. It was found to wrap itself around tree branches and other vegetation downstream. Of the material passing through the screen at the Sharpe & Kirkbride stilling pond CSO 51% was found to be fine paper. At the Extended stilling pond CSO this figure was 28%.

8.8 The retention efficiencies measured for the screen meshes are the maximum that could be achieved by these screening media. In practice, other factors such as the efficiency of the cleaning mechanism and the seals around the screen installation will reduce the overall screen retention efficiency.

8.9 The total mass of gross solids presented to a CSO screen has been shown to increase with the mean overflow intensity of the storm event and it is possible to predict the result using a simple model based on the upstream population and average usage figures of sanitary products and toilet tissue.

8.10 There appears to be different transport mechanisms for different types of gross solids. Faeces, fine paper, paper towels, sanitary towels and sweet wrappers are transported continually in the sewerage system. Condoms, disposable nappies, clear plastic wrappers and tea bags require a threshold velocity of flow before they are transported.

8.11 Further work needs to be done on the other factors which influence screen retention efficiency and a detailed investigation should be done on gross solids transport mechanisms to produce a more detailed model.

REFERENCES

ANDERSON J A and BAHMANI M J, *"The Hydraulic Behaviour of Perforated Plates using Water and Solid Material"*, J. Water pollution Control, Vol. 84, p.111,1985

BALMFORTH D J, *"Flow over Side Weirs"*, PhD Thesis, University of Sheffield, August 1978

BALMFORTH D J and HENDERSON R J, "*A guide to the Design of Storm Overflow Structures*", Report No. ER 304E, WRc plc, April 1988

BROWN J M, *"Retrofitting of Screens and Screening Handling"*, P D Report No. 93/2, Yorkshire Water, March 1994

BURCHMORE S and GREEN M, *"Interim Report on Sewage Derived Aesthetic Pollution"*, Report No. FR0339, FWR, March 1993

CHADWICK E, *"Report on the Sanitary Condition of the Labouring Population of Great Britain"*, London, 1842

COOKMAN I J R, "*Operational Efficiency of Inlet Works Screens*", Journal Water Pollution Control, Vol. 85, No. 4, pp 445-458, 1986

COOTES T F and GREEN M J, "*Monitoring a Vortex Storm Sewage Overflow with Peripheral Spill*", Report No. UM 1092, WRc plc, March 1990

EUROPEAN COMMISSION, *"Urban Waste Water Treatment Directive"*, EC Directive No. 91/271/EEC, Official Journal L135, 30 May 1991

FRIED E and IDELCHIK I E, *"Flow Resistance - A Design Guide for Engineers"*, Hemisphere Publishing Corporation, 1989

HEDLEY G and KING M V, *"Suggested correlations between Storm Sewage Overflow characteristics and Storm Overflow Performance"*, Procs. Inst. Civil Engineers, Vol. 48, pp 399-411, 1971

HOPKINS P D and MARSHALL R J, *"Storm Sewage Overflow Screens Design and Operation"*, Symposium on Developments in Storm Sewerage Management, Sheffield City Polytechnic & Institute of Public Health Engineers, Sheffield, March 24-25 1986

HUBBARD A M and CRABTREE H E, "*Some observations on Screening and Screenings Treatment at Sewage Treatment Works*", J. Water Pollution Control, Vol. 85, No. 4, pp 488-497, 1986

HYDRAULICS RESEARCH, *"WALLRUS User Manual"*, 3rd Edition, Hydraulics Research, Wallingford, August 1989

HYDRAULICS RESEARCH, *"MOSQUITO User Manual"*, Hydraulics Research, Wallingford, October 1989

JEFFRIES C, *"Methods of estimating the discharge of Gross Solids from Combined Sewer Systems"*, Water Science Technology, Vol. 26, No. 5-6, pp 1295-1304, 1992

LONSDALE K G, BALMFORTH D J, NUSSEY B B and WALSH A M, *"Monitoring Combined Sewer Overflow Performance"*, Report No. UM 1388, WRc plc, April 1993

LONSDALE K G, *"Monitoring of Storm Sewer Overflows"*, PhD Thesis, Sheffield Hallam University, June 1994

MINISTRY OF HOUSING AND LOCAL GOVERNMENT, *"Technical Committee on Storm Overflows and the Disposal of Storm Sewage - Final Report"*, HMSO, London, 1970

MORRIS G, *"Consent standards for Storm Sewage Overflows"*, Proc. Semin. Storm Overflows - Practice and Performance", Birmingham University and Hydro Research and Development, April 1991

MUTZNER H, *"Visible Pollution from Combined Sewer Overflows"*, Fourth International Conference on Urban Storm Drainage, Lausanne, 1987

NATIONAL RIVERS AUTHORITY, *"General Guidance Note for Preparatory Work for AMP2"*, Version 2, NRA, October 1993

NATIONAL RIVERS AUTHORITY, *"General Guidance Note for Preparatory Work for AMP2"*, Version 2, NRA, December 1993

NATIONAL RIVERS AUTHORITY, *"Proposals for Statutory Water Quality Objectives"*, Water Quality Series No. 5, NRA, December 1991

O'SULLIVAN, *"Review of the Performance of Storm Sewage Overflow Structures with respect to Aesthetic Criteria"*, Report No. UM 1037, WRc plc, March 1990

PAGE S J, "Quantifying the Screenings Problem at Sewage Treatment Works", J. Water Pollution Control, Vol. 85, No. 4, 1986

REALEY G J and EFLEIN H, *"An evaluation of the screenability of Sanitary Products"*, Report No. UC 911, WRc plc, November 1990

ROYAL COMMISSION ON SEWAGE DISPOSAL, *"Commissioners appointed to inquire into what methods of treating and disposing of sewage may be properly adopted"*, Fifth Report Cd 4278, London, 1908

SAUL A J, RUFF S J, WALSH A M and GREEN M J, *"Laboratory studies of CSO Performance"*, Report No. UM 1421, WRc plc, December 1993

SAUL A J, MARSH P M and CROCKETT C P, *"A strategy for the Monitoring of Pollutants in Sewers, Overflows and Tanks"*, Proc. Fifth International Conference Urban Storm Drainage, Osaka, 1990

SAUL A J and MURRELL M D, *"Design Considerations and Maintenance of Storm Sewage Overflows with Particular Emphasis on Storage"*, Symposium on Developments in Storm Sewerage Management, Sheffield City Polytechnic & Institute of Public Health Engineers, Sheffield, March 24-25 1986

SCOTTISH DEVELOPMENT DEPARTMENT, *"Storm Sewage Separation and Disposal"*, Report of the Working Party on Storm Sewage (Scotland), HMSO, Edinburgh, 1977

SIDWICK J M, *"Screenings and Grit in Sewage: Removal, Treatment and Disposal. Preliminary Report"*, CIRIA Technical Note 119, 1984

SIDWICK J M, *"Screenings and Grit in Sewage: Removal, Treatment and Disposal. Phase 2: Further cost aspects of screening practice"*, CIRIA Technical Note 122, 1985

SIDWICK J M, *"Screenings and Grit in Sewage: Removal, Treatment and Disposal. Phase 3: Storm Water overflows and pumping stations"*, CIRIA Technical Note 132, 1988

THOMAS D K, BROWN S J and HARRINGTON D W, *"Screening at Marine Outfall Headworks"*, J. IWEM, Vol. 3, December 1989

THOMPSON B, WEBSTER S and RENVOIZE T, *"Portrack STW, Inlet Screen Evaluation"*, Northumbrian Water Ltd., March 1993

UK WATER INDUSTRY RESEARCH LTD, *"Combined Sewer Overflows"*, Report No. WWT 001, U K WIRL, London, November 1994

WALSH A M, *"The Gross Solids Sampler - Development of a sampler for Combined Sewer Overflows"*, Report No. UM 1172, WRc plc, November 1990
WATER RESEARCH CENTRE, *"Sewerage Rehabilitation Manual"*, WRc plc, Swindon, 1984

YEH H H and STRESTHA M, *"Free-surface Flow through Screen"*, J Hydraulic Eng., Vol 115, No. 10, pp 1371-1385, October 1989

BIBLIOGRAPHY

BAHMANI M J and ANDERSON J A, *"The Hydraulic Behaviour of a Cup Screen using Water and Solid Material"*, J. Water pollution Control, Vol. 84, p.417,1985

BAINES W D and PETERSON E G, *"An Investigation of Flow through Screens"*, Trans ASME, Vol. 73, pp 467-480, July 1951

BALMFORTH D J, *"Effectiveness of Storm Sewage Overflow Structures in handling Gross Polluting Solids"*, International Conference in Combined Sewage Overflows and Effects of Receiving Streams, Wageningen, Holland, 1986

BALMFORTH D J, SAUL A J and CLIFFORDE I T, *"Guide to the Design of Combined Sewer overflow Structures"*, Report No. FR 0488, FWR, November 1994

BALMFORTH D J and DRINKWATER A, *"A guide to the Design of Storm Overflow Structures"*, Report No. ER 304E, WRc plc, December 1993

BROWN S J, HARRINGTON D W and THOMAS DK, *"The removal of screenings from the sewage flow at marine outfall headworks"*, Conference Environmental Contamination, Venice, October 2-6 1988

BUTLER D, *"A Small Scale Study of Wastewater Discharges from Domestic Appliances"*, J. IWEM, Vol. 5, No. 2, pp 178-189

CARGILL J D, *"A History of Sewage Works Machinery"*, Journal Institute of Water Pollution Control, Vol. 74, No. 4, pp 430-454, 1975

CRABTREE R W, *"Sediments in Sewers"*, J. IWEM, Vol. 3, December 1989

DAVIES J W, *"Laboratory Study related to the First Foul Flush in Combined Sewers"*, Fourth International Conference on Urban Storm Drainage, Lausanne, 1987

DAY C, *"Fine Screening of Sewage"*, Water and Waste Treatment, Vol. 37, Issue 4, April 1994

DETECTRONIC LTD, *"Detectronic Installation and Operating Instructions - I S Surveylogger and Rainlogger Systems"*, Detectronic Ltd.

DINIUS S H, *"Public Perception in Water Quality Evaluation"*, Water Resources Bulletin, Vol. 17, pp 116 -121, 1981

DRINKWATER A R, *"Wastewater Quality Surveys - Improving CSO Monitoring"*, WRc plc, 1993

ELLIS J B, *"The characterisation of particulate solids and quality of water discharged from an urban catchment"*, Proc. IAHS-UNESCO, pp 283-291, IAHS publ No. 123, Amsterdam, 1977

ENVIRONMENTAL PROTECTION AGENGY, *"In-Sewer Fixed Screening of Combined Sewer Overflows"*, EPA, October 1970

GEIGER W F, *"Characteristics of Combined Sewer Runoff"*, Proc. Third International Conference on Urban Storm Drainage, Goteburg, Sweden, 1984

GREEN M J, *"Assessment of Sewer Overflow Performance"*, Report UM 1193, WRc plc, March 1991

HADDON M, *"Out of Sight? Out of your mind"*, Water Bulletin, 17 February 1995

HELLIWELL P, *"Storm overflow - The Problem", Proc. Semin. Storm Overflows - Practice and Performance"*, Birmingham University and Hydro Research and Development, April 1991

HELLIWELL P, SMISSION B and BENNETT N, *"A Flood of Pollution: Time for Action"*, Surveyor, January 1988

INSTITUTION OF WATER AND ENVIRONMENTAL MANAGEMENT, *"Preliminary Processes"*, Handbook of UK wastewater practice, IWEM, 1992

JEFFRIES C and ASHLEY R M, *"Gross Solids in Sewer Systems: Temporal and Catchment Based Relationships"*, IAWQ 17th Biennial Conference, Budapest, Hungary, 24-30 July 1994

O'KELLY L, *"Disposable assets!"*, Cosmopolitan Magazine 1992

PRUTER A T, *"Sources, Quantities and Distribution of Persitent Plastics in the Marine Environment"*, J. Marine Pollution Control, Vol. 18, pp 305-310, 1987

REALEY G, *"A Chamber of Horrors"*, Water Bulletin, Pt. 527, pp 8-9

RICHARDS R T, *"Alternative Water Screening for Thermal Power Plants"*, ASCE, J. Hydraulic Eng., Vol. 114, No. 6, June 1988

RIDING E, BALMFORTH D J and GREEN M, *"Monitoring the Performance of Screens at Combined Sewer Overflows"*, Report No. UM 1433, WRc plc, April 1994

SADGROVE J, *"The Protection Racket"*, The Guardian, Tuesday June 9 1992

SHARMA S K, *"An Experimental Investigation of the Transport of Solids in Building Drains"*, J Inst. Engineers (India), Vol 65, pp 27-28, October 1984

SHARPE D E & KIRKBRIDE T W, *"Storm Water Overflows, the Operation and Design of a Stilling pond"*, Proc. Instn. Civ. Engrs., Vol. 13, pp 445 - 466

STANFIELD G, *"Disposal of Sewage from Coastal Towns"*, Royal Society of Health Journal, Vol. 2, pp 53-8, 1982

STANIFORTH S and VEVERS A, *"A study of solid refuse deposits in the River Don in Urban Sheffield"*, National Rivers Authority, February 1994

THORPE A D, "*Guide to Sewer Flow Survey Analysis Techniques - Interim Notes*", WRc Engineering, 1986

TYACK J N, HEDGES P D and SMISSON R P M, "*A device for determining the settling velocity grading of storm sewage*", 6th International Conference on Urban Storm Drainage, Niagara Falls, Ontario, Canada, September 12-17, 1993

WATER RESEARCH CENTRE, "*A Guide to Short Term Flow Surveys of Sewer Systems*", WRc plc

WATER RESEARCH CENTRE, "*Sewer Survey Analysis Software, SSAS User Guide*", WRc plc, Version 2.0, 1990

WATER RESEARCH CENTRE, "*Sewer Survey Analysis Software (SSAS) - Operation Notes*", WRc plc, Version 2.0

WELSH WATER AND FRIENDS OF THE EARTH CYMRU, *"ODDS and PODS Report"*, June 1993

WILSON C, *"Bin There, Do That"*, The Guardian, Wednesday 7th April 1993

WOMEN'S ENVIRONMENTAL NETWORK, *"Sanitary Protection, Women's Health and the Environment"*, WEN, April 1993

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	31/10/94	79.57		2	31/10/94	99.56	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	25	0	0	25	0	0	0	0
F Paper, Veg & Faeces	550	250	200	1000	350	150	150	650
Sanitary towels	125	0	0	125	60	0	0	60
Tampons	0	0	0	0	0	0	0	0
TOTAL	700	250	200	1150	410	150	150	710

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	31/10/94	79.57		2	31/10/94	99.56	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	2.2	0	0	0	0.0
F Paper, Veg & Faeces	55	25	20	87.0	54	23	23	91.5
Sanitary towels	100	0	0	10.9	100	0	0	8.5
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	61	22	17	100	58	21	21	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	31/10/94	73.25		4	31/10/94	85.57	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	850	325	275	1450	625	225	250	1100
Sanitary towels	225	0	0	225	150	0	0	150
Tampons	75	0	0	75	100	0	0	100
TOTAL	1150	325	275	1750	875	225	250	1350

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	31/10/94	73.25		4	31/10/94	85.57	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	59	22	19	82.9	57	20	23	81.5
Sanitary towels	100	0	0	12.9	100	0	0	11.1
Tampons	100	0	0	4.3	100	0	0	7.4
TOTAL	66	18	16	100	65	17	18	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	31/10/94	90.90		6	31/10/94	83.56	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	675	250	175	1100	825	225	175	1225
Sanitary towels	225	0	0	225	350	0	0	350
Tampons	125	0	0	125	0	0	0	0
TOTAL	1025	250	175	1450	1175	225	175	1575

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	31/10/94	90.90		6	31/10/94	83.56	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	61	23	16	75.9	67	18	14	77.8
Sanitary towels	100	0	0	15.5	100	0	0	22.2
Tampons	100	0	0	8.6	0	0	0	0.0
TOTAL	71	17	12	100	75	14	11	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No. 1	Date 11/01/94	Flow (l/s) 62.58		Test No. 2	Date 11/01/94	Flow (l/s) 66.08	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	550	300	250	1100	650	250	225	1125
Sanitary towels	200	0	0	200	175	0	0	175
Tampons	0	0	0	0	75	0	0	75
TOTAL	750	300	250	1300	900	250	225	1375

Percentage of Sample Retained by each Screen

	Test No. 1	Date 11/01/94	Flow (l/s) 62.58		Test No. 2	Date 11/01/94	Flow (l/s) 66.08	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	50	27	23	84.6	58	22	20	81.8
Sanitary towels	100	0	0	15.4	100	0	0	12.7
Tampons	0	0	0	0.0	100	0	0	5.5
TOTAL	58	23	19	100	66	18	16	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No. 3	Date 11/01/94	Flow (l/s) 63.93		Test No. 4	Date 11/01/94	Flow (l/s) 61.76	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	10	0	0	10	0	0	0	0
F Paper, Veg & Faeces	625	375	250	1250	375	225	175	775
Sanitary towels	175	0	0	175	75	0	0	75
Tampons	0	0	0	0	50	0	0	50
TOTAL	810	375	250	1435	500	225	175	900

Percentage of Sample Retained by each Screen

	Test No. 3	Date 11/01/94	Flow (l/s) 63.93		Test No. 4	Date 11/01/94	Flow (l/s) 61.76	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.7	0	0	0	0.0
F Paper, Veg & Faeces	50	30	20	87.1	48	29	23	86.1
Sanitary towels	100	0	0	12.2	100	0	0	8.3
Tampons	0	0	0	0.0	100	0	0	5.6
TOTAL	57	26	17	100	56	25	19	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/01/94	69.43		6	11/01/94	79.61	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	775	300	250	1325	625	275	250	1150
Sanitary towels	125	0	0	125	100	0	0	100
Tampons	25	0	0	25	75	0	0	75
TOTAL	925	300	250	1475	800	275	250	1325

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/01/94	69.43		6	11/01/94	79.61	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	58	23	19	89.8	54	24	22	86.8
Sanitary towels	100	0	0	8.5	100	0	0	7.5
Tampons	100	0	0	1.7	100	0	0	5.7
TOTAL	63	20	17	100	60	21	19	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No. 7	Date 11/01/94	Flow (l/s) 67.66		Test No. 8	Date 11/01/94	Flow (l/s) 63.97	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	850	275	250	1375	650	375	250	1275
Sanitary towels	175	0	0	175	100	0	0	100
Tampons	25	0	0	25	0	0	0	0
TOTAL	1050	275	250	1575	750	375	250	1375

Percentage of Sample Retained by each Screen

	Test No. 7	Date 11/01/94	Flow (l/s) 67.66		Test No. 8	Date 11/01/94	Flow (l/s) 63.97	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	62	20	18	87.3	51	29	20	92.7
Sanitary towels	100	0	0	11.1	100	0	0	7.3
Tampons	100	0	0	1.6	0	0	0	0.0
TOTAL	67	17	16	100	55	27	18	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/07/94	?		2	11/07/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	0	0	0	0
F Paper, Veg & Faeces	475	250	175	900	575	250	250	1075
Sanitary towels	0	0	0	0	125	0	0	125
Tampons	0	0	0	0	25	0	0	25
TOTAL	487	250	175	912	725	250	250	1225

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/07/94	?		2	11/07/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.3	0	0	0	0.0
F Paper, Veg & Faeces	53	28	19	98.7	53	23	23	87.8
Sanitary towels	0	0	0	0.0	100	0	0	10.2
Tampons	0	0	0	0.0	100	0	0	2.0
TOTAL	53	28	19	100	60	20	20	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/07/94	?		4	11/07/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	6	0	0	6
F Paper, Veg & Faeces	550	250	225	1025	500	250	225	975
Sanitary towels	50	0	0	50	250	0	0	250
Tampons	50	0	0	50	0	0	0	0
TOTAL	662	250	225	1137	756	250	225	1231

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/07/94	?		4	11/07/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.1	100	0	0	0.5
F Paper, Veg & Faeces	54	24	22	90.1	51	26	23	79.2
Sanitary towels	100	0	0	4.4	100	0	0	20.3
Tampons	100	0	0	4.4	0	0	0	0.0
TOTAL	58	22	20	100	62	20	18	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/07/94	?		6	11/07/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	450	200	175	825	450	250	175	875
Sanitary towels	150	0	0	150	150	0	0	150
Tampons	50	0	0	50	0	0	0	0
TOTAL	650	200	175	1025	606	250	175	1031

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/07/94	?		6	11/07/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.6
F Paper, Veg & Faeces	55	24	21	80.5	51	29	20	84.9
Sanitary towels	100	0	0	14.6	100	0	0	14.5
Tampons	100	0	0	4.9	0	0	0	0.0
TOTAL	63	20	17	100	59	24	17	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/08/94	?		2	11/08/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	394	175	164	733	725	245	255	1225
Sanitary towels	31	0	0	31	162	0	0	162
Tampons	0	0	0	0	148	0	0	148
TOTAL	425	175	164	764	1035	245	255	1535

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/08/94	?		2	11/08/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	54	24	22	95.9	59	20	21	79.8
Sanitary towels	100	0	0	4.1	100	0	0	10.6
Tampons	0	0	0	0.0	100	0	0	9.6
TOTAL	56	23	21	100	67	16	17	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/08/94	?		4	11/08/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	562	254	187	1003	441	177	168	786
Sanitary towels	106	0	0	106	202	0	0	202
Tampons	53	0	0	53	75	0	0	75
TOTAL	721	254	187	1162	718	177	168	1063

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/08/94	?		4	11/08/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	56	25	19	86.3	56	23	21	73.9
Sanitary towels	100	0	0	9.1	100	0	0	19.0
Tampons	100	0	0	4.6	100	0	0	7.1
TOTAL	62	22	16	100	67	17	16	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No. 5	Date 11/08/94	Flow (l/s) ?		Test No. 6	Date 11/08/94	Flow (l/s) ?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	713	281	245	1239	938	356	291	1585
Sanitary towels	230	0	0	230	33	0	0	33
Tampons	205	0	0	205	30	0	0	30
TOTAL	1148	281	245	1674	1001	356	291	1648

Percentage of Sample Retained by each Screen

	Test No. 5	Date 11/08/94	Flow (l/s) ?		Test No. 6	Date 11/08/94	Flow (l/s) ?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	58	23	20	74.0	59	22	18	96.2
Sanitary towels	100	0	0	13.7	100	0	0	2.0
Tampons	100	0	0	12.2	100	0	0	1.8
TOTAL	68	17	15	100	61	21	18	100

Testing of Three Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	11/08/94	?		8	11/08/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	6	0	0	6
F Paper, Veg & Faeces	799	342	305	1446	532	240	211	983
Sanitary towels	0	0	0	0	148	0	0	148
Tampons	65	0	0	65	0	0	0	0
TOTAL	870	342	305	1517	686	240	211	1137

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	11/08/94	?		8	11/08/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.4	100	0	0	0.5
F Paper, Veg & Faeces	55	24	21	95.3	54	24	21	86.5
Sanitary towels	0	0	0	0.0	100	0	0	13.0
Tampons	100	0	0	4.3	0	0	0	0.0
TOTAL	57	23	20	100	60	21	19	100

Testing of a 6 mm Round Perforated Polyurethane Sheet

Mass of Sample Collected

	Test No. 1	Date 28/2/95	Flow (l/s) 97.70		Test No. 2	Date 28/2/95	Flow (l/s) 115.42	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	497	565	894	1956	160	98	97	355
Sanitary towels	127	0	0	127	57	0	0	57
Tampons	48	0	0	48	0	0	0	0
TOTAL	672	565	894	2131	223	98	97	418

Percentage of Sample Retained by each Screen

	Test No. 1	Date 28/2/95	Flow (l/s) 97.70		Test No. 2	Date 28/2/95	Flow (l/s) 115.42	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.5
F Paper, Veg & Faeces	25	29	46	91.8	45	28	27	84.9
Sanitary towels	100	0	0	6.0	100	0	0	13.6
Tampons	100	0	0	2.2	0	0	0	0.0
TOTAL	32	26	42	100	53	24	23	100

Mass of Sample Collected

Testing of a 6 mm Round Perforated Polyurethane Sheet

	Test No. 3	Date 28/2/95	Flow (l/s) 81.54		Test No. 4	Date 28/2/95	Flow (l/s) 95.98	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	0	0	0	0
F Paper, Veg & Faeces	219	104	121	444	222	90	111	423
Sanitary towels	0	0	0	0	32	0	0	32
Tampons	51	0	0	51	54	0	0	54
TOTAL	282	104	121	507	308	90	111	509

Percentage of Sample Retained by each Screen

	Test No. 3	Date 28/2/95	Flow (l/s) 81.54		Test No. 4	Date 28/2/95	Flow (l/s) 95.98	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	2.4	0	0	0	0.0
F Paper, Veg & Faeces	49	23	27	87.5	52	21	26	83.1
Sanitary towels	0	0	0	0.0	100	0	0	6.3
Tampons	100	0	0	10.1	100	0	0	10.6
TOTAL	56	20	24	100	60	18	22	100

Testing of a 6 mm Round Perforated Polyurethane Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	28/2/95	76.16		6	28/2/95	95.15	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	12	0	0	12
F Paper, Veg & Faeces	265	88	98	451	387	128	132	647
Sanitary towels	63	0	0	63	88	0	0	88
Tampons	41	0	0	41	75	0	0	75
TOTAL	369	88	98	555	562	128	132	822

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	28/2/95	76.16		6	28/2/95	95.15	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.5
F Paper, Veg & Faeces	59	20	22	81.3	60	20	20	78.7
Sanitary towels	100	0	0	11.3	100	0	0	10.7
Tampons	100	0	0	7.4	100	0	0	9.1
TOTAL	66	16	18	100	68	16	16	100

Testing of a 6 mm Round Perforated Polyurethane Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	28/2/95	92.91		8	28/2/95	60.22	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	245	104	92	441	355	185	182	722
Sanitary towels	56	0	0	56	28	0	0	28
Tampons	138	0	0	138	63	0	0	63
TOTAL	439	104	92	635	452	185	182	819

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	28/2/95	92.91		8	28/2/95	60.22	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.7
F Paper, Veg & Faeces	56	24	21	69.5	49	26	25	88.2
Sanitary towels	100	0	0	8.8	100	0	0	3.4
Tampons	100	0	0	21.7	100	0	0	7.7
TOTAL	69	16	15	100	55	23	22	100

Mass of Sample Collected

Testing of a 6 mm Round Perforated Polyurethane Sheet

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	28/2/95	98.12		10	28/2/95	86.01	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	18	0	0	18	0	0	0	0
F Paper, Veg & Faeces	316	124	179	619	287	123	106	516
Sanitary towels	71	0	0	71	74	0	0	74
Tampons	0	0	0	0	0	0	0	0
TOTAL	405	124	179	708	361	123	106	590

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	28/2/95	98.12		10	28/2/95	86.01	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	2.6	0	0	0	0.0
F Paper, Veg & Faeces	51	20	29	87.4	56	24	21	87.5
Sanitary towels	100	0	0	10.0	100	0	0	12.5
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	57	18	25	100	61	21	18	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No. 1	Date 22/11/94	Flow (l/s) 82.43		Test No. 2	Date 22/11/94	Flow (l/s) 78.42	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	869	305	326	1500	545	249	191	985
Sanitary towels	204	0	0	204	91	0	0	91
Tampons	33	0	0	33	102	0	0	102
TOTAL	1106	305	326	1737	738	249	191	1178

Percentage of Sample Retained by each Screen

	Test No. 1	Date 22/11/94	Flow (l/s) 82.43		Test No. 2	Date 22/11/94	Flow (l/s) 78.42	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	58	20	22	86.4	55	25	19	83.6
Sanitary towels	100	0	0	11.7	100	0	0	7.7
Tampons	100	0	0	1.9	100	0	0	8.7
TOTAL	64	17	19	100	63	21	16	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No. 3	Date 22/11/94	Flow (l/s) 78.50		Test No. 4	Date 22/11/94	Flow (l/s) 71.82	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	640	262	228	1130	711	294	202	1207
Sanitary towels	113	0	0	113	96	0	0	96
Tampons	71	0	0	71	100	0	0	100
TOTAL	824	262	228	1314	907	294	202	1403

Percentage of Sample Retained by each Screen

	Test No. 3	Date 22/11/94	Flow (l/s) 78.50		Test No. 4	Date 22/11/94	Flow (l/s) 71.82	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	57	23	20	86.0	59	24	17	86.0
Sanitary towels	100	0	0	8.6	100	0	0	6.8
Tampons	100	0	0	5.4	100	0	0	7.1
TOTAL	63	20	17	100	65	21	14	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	22/11/94	83.16		6	22/11/94	66.30	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	744	266	194	1204	813	258	206	1277
Sanitary towels	226	0	0	226	165	0	0	165
Tampons	147	0	0	147	106	0	0	106
TOTAL	1117	266	194	1577	1084	258	206	1548

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	22/11/94	83.16		6	22/11/94	66.30	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	62	22	16	76.3	64	20	16	82.5
Sanitary towels	100	0	0	14.3	100	0	0	10.7
Tampons	100	0	0	9.3	100	0	0	6.8
TOTAL	71	17	12	100	70	17	13	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	28/11/94	70.93		2	28/11/94	92.45	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	931	233	204	1368	351	226	157	734
Sanitary towels	359	0	0	359	122	0	0	122
Tampons	120	0	0	120	0	0	0	0
TOTAL	1410	233	204	1847	473	226	157	856

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	28/11/94	70.93		2	28/11/94	92.45	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	68	17	15	74.1	48	31	21	85.7
Sanitary towels	100	0	0	19.4	100	0	0	14.3
Tampons	100	0	0	6.5	0	0	0	0.0
TOTAL	76	13	11	100	55	27	18	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No. 3	Date 28/11/94	Flow (l/s) 83.44		Test No. 4	Date 28/11/94	Flow (l/s) 89.80	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	0	0	0	0
F Paper, Veg & Faeces	71	182	148	401	448	261	196	905
Sanitary towels	169	0	0	169	358	0	0	358
Tampons	67	0	0	67	43	0	0	43
TOTAL	313	182	148	643	849	261	196	1306

Percentage of Sample Retained by each Screen

	Test No. 3	Date 28/11/94	Flow (l/s) 83.44		Test No. 4	Date 28/1.1/94	Flow (l/s) 89.80	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.9	0	0	0	0.0
F Paper, Veg & Faeces	18	45	37	62.4	50	29	22	69.3
Sanitary towels	100	0	0	26.3	100	0	0	27.4
Tampons	100	0	0	10.4	100	0	0	3.3
TOTAL	49	28	23	100	65	20	15	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	28/11/94	70.72		6	28/11/94	81.15	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	0	0	0	0
F Paper, Veg & Faeces	329	276	227	832	262	204	166	632
Sanitary towels	139	0	0	139	128	0	0	128
Tampons	90	0	0	90	179	0	0	179
TOTAL	564	276	227	1067	569	204	166	939

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	28/11/94	70.72		6	28/11/94	81.15	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.6	0	0	0	0.0
F Paper, Veg & Faeces	40	33	27	78.0	41	32	26	67.3
Sanitary towels	100	0	0	13.0	100	0	0	13.6
Tampons	100	0	0	8.4	100	0	0	19.1
TOTAL	53	26	21	100	60	22	18	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No. 7	Date 28/11/94	Flow (l/s) 81.46		Test No. 8	Date 28/11/94	Flow (l/s) 85.38	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	0	0	0	0
F Paper, Veg & Faeces	246	196	152	594	266	195	159	620
Sanitary towels	39	0	0	39	137	0	0	137
Tampons	0	0	0	0	71	0	0	71
TOTAL	297	196	152	645	474	195	159	828

Percentage of Sample Retained by each Screen

	Test No. 7	Date 28/11/94	Flow (l/s) 81.46		Test No. 8	Date 28/11/94	Flow (l/s) 85.38	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.9	0	0	0	0.0
F Paper, Veg & Faeces	41	33	26	92.1	43	31	26	74.9
Sanitary towels	100	0	0	6.0	100	0	0	16.5
Tampons	0	0	0	0.0	100	0	0	8.6
TOTAL	46	30	24	100	57	24	19	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No. 1	Date 12/12/94	Flow (l/s) 78.36		Test No. 2	Date 12/12/94	Flow (l/s) 109.04	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	543	246	195	984	350	206	159	715
Sanitary towels	30	0	0	30	91	0	0	91
Tampons	0	0	0	0	0	0	0	0
TOTAL	573	246	195	1014	441	206	159	806

Percentage of Sample Retained by each Screen

	Test No. 1	Date 12/12/94	Flow (l/s) 78.36		Test No. 2	Date 12/12/94	Flow (l/s) 109.04	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	55	25	20	97.0	49	29	22	88.7
Sanitary towels	100	0	0	3.0	100	0	0	11.3
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	57	24	19	100	55	25	20	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	12/12/94	84.49		4	12/12/94	93.81	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	417	227	195	839	362	192	165	719
Sanitary towels	54	0	0	54	57	0	0	57
Tampons	27	0	0	27	0	0	0	0
TOTAL	498	227	195	920	419	192	165	776

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	12/12/94	84.49		4	12/12/94	93.81	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	50	27	23	91.2	50	27	23	92.7
Sanitary towels	100	0	0	5.9	100	0	0	7.3
Tampons	100	0	0	2.9	0	0	0	0.0
TOTAL	54	25	21	100	54	25	21	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	12/12/94	105.38		6	12/12/94	96.00	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	12	0	0	12
F Paper, Veg & Faeces	464	194	198	856	353	203	177	733
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	464	194	198	856	365	203	177	745

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	12/12/94	105.38		6	12/12/94	96.00	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.6
F Paper, Veg & Faeces	54	23	23	100.0	48	28	24	98.4
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	23	23	100	49	27	24	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	12/12/94	88.05		8	12/12/94	76.91	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	329	154	197	680	430	175	163	768
Sanitary towels	37	0	0	37	114	0	0	114
Tampons	33	0	0	33	0	0	0	0
TOTAL	399	154	197	750	544	175	163	882

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	12/12/94	88.05		8	12/12/94	76.91	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	48	23	29	90.7	56	23	21	87.1
Sanitary towels	100	0	0	4.9	100	0	0	12.9
Tampons	100	0	0	4.4	0	0	0	0.0
TOTAL	53	21	26	100	62	20	18	100

Long Lane Sewage Treatment Works

Mass of Sample Collected

Testing of a 6.0 mm Square Perforated Steel Sheet

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	12/12/94	74.91		10	12/12/94	76.37	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	353	199	186	738	319	177	153	649
Sanitary towels	26	0	0	26	22	0	0	22
Tampons	43	0	0	43	85	0	0	85
TOTAL	422	199	186	807	426	177	153	756

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	12/12/94	74.91		10	12/12/94	76.37	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	48	27	25	91.4	49	27	24	85.8
Sanitary towels	100	0	0	3.2	100	0	0	2.9
Tampons	100	0	0	5.3	100	0	0	11.2
TOTAL	52	25	23	100	56	24	20	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	11	12/12/94	63.46		12	12/12/94	71.45	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	6	0	0	6
F Paper, Veg & Faeces	302	167	152	621	443	199	212	854
Sanitary towels	44	0	0	44	60	0	0	60
Tampons	69	0	0	69	132	0	0	132
TOTAL	421	167	152	740	641	199	212	1052

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	11	12/12/94	63.46		12	12/12/94	71.45	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.8	100	0	0	0.6
F Paper, Veg & Faeces	49	27	24	83.9	52	23	25	81.2
Sanitary towels	100	0	0	5.9	100	0	0	5.7
Tampons	100	0	0	9.3	100	0	0	12.5
TOTAL	57	23	20	100	61	19	20	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	13	12/12/94	72.41		14	12/12/94	66.04	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	6	0	0	6
F Paper, Veg & Faeces	509	215	201	925	432	223	176	831
Sanitary towels	39	0	0	39	29	0	0	29
Tampons	45	0	0	45	26	0	0	26
TOTAL	599	215	201	1015	493	223	176	892

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	13	12/12/94	72.41		14	12/12/94	66.04	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.6	100	0	0	0.7
F Paper, Veg & Faeces	55	23	22	91.1	52	27	21	93.2
Sanitary towels	100	0	0	3.8	100	0	0	3.3
Tampons	100	0	0	4.4	100	0	0	2.9
TOTAL	59	21	20	100	55	25	20	100

Testing of a 6.0 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	15	12/12/94	86.08		16	12/12/94	61.67	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	252	157	161	570	317	177	156	650
Sanitary towels	54	0	0	54	43	0	0	43
Tampons	0	0	0	0	0	0	0	0
TOTAL	306	157	161	624	366	177	156	699

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	15	12/12/94	86.08		16	12/12/94	61.67	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.9
F Paper, Veg & Faeces	44	28	28	91.3	49	27	24	93.0
Sanitary towels	100	0	0	8.7	100	0	0	6.2
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	49	25	26	100	53	25	22	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	2/12/94	77.66		2	2/12/94	76.75	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	18	0	0	18
F Paper, Veg & Faeces	141	189	91	421	548	0	0	548
Sanitary towels	17	0	0	17	127	200	123	450
Tampons	32	0	0	32	0	0	0	0
TOTAL	190	189	91	470	693	200	123	1016

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	2/12/94	77.66		2	2/12/94	76.75	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.8
F Paper, Veg & Faeces	33	45	22	89.6	100	0	0	53.9
Sanitary towels	100	0	0	3.6	28	44	27	44.3
Tampons	100	0	0	6.8	0	0	0	0.0
TOTAL	41	40	19	101	68	20	12	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No. 3	Date 2/12/94	Flow (l/s) 50.41		Test No. 4	Date 2/12/94	Flow (l/s) 76.41	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	218	158	89	465	124	139	84	347
Sanitary towels	0	0	0	0	41	0	0	41
Tampons	33	0	0	33	0	0	0	0
TOTAL	251	158	89	498	165	139	84	388

Percentage of Sample Retained by each Screen

	Test No. 3	Date 2/12/94	Flow (l/s) 50.41		Test No. 4	Date 2/12/94	Flow (l/s) 76.41	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	47	34	19	93.4	36	40	24	89.4
Sanitary towels	0	0	0	0.0	100	0	0	10.6
Tampons	100	0	0	6.6	0	0	0	0.0
TOTAL	50	32	18	100	42	36	22	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	2/12/94	65.40		6	2/12/94	75.81	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	12	0	0	12
F Paper, Veg & Faeces	137	162	88	387	319	190	114	623
Sanitary towels	34	0	0	34	58	0	0	58
Tampons	0	0	0	0	33	0	0	33
TOTAL	177	162	88	427	422	190	114	726

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	2/12/94	65.40		6	2/12/94	75.81	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.4	100	0	0	1.7
F Paper, Veg & Faeces	35	42	23	90.6	51	30	18	85.8
Sanitary towels	100	0	0	8.0	100	0	0	8.0
Tampons	0	0	0	0.0	100	0	0	4.5
TOTAL	41	38	21	100	58	26	16	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	9/12/94	100.84		2	9/12/94	101.42	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	344	308	151	803	443	259	220	922
Sanitary towels	195	0	0	195	87	0	0	87
Tampons	84	0	0	84	55	0	0	55
TOTAL	623	308	151	1082	585	259	220	1064

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	9/12/94	100.84		2	9/12/94	101.42	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	43	38	19	74.2	48	28	24	86.7
Sanitary towels	100	0	0	18.0	100	0	0	8.2
Tampons	100	0	0	7.8	100	0	0	5.2
TOTAL	58	28	14	100	55	24	21	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No. 3	Date 9/12/94	Flow (l/s) 129.14		Test No. 4	Date 9/12/94	Flow (l/s) 101.08	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	266	164	145	575	353	233	198	784
Sanitary towels	35	0	0	35	37	0	0	37
Tampons	0	0	0	0	0	0	0	0
TOTAL	301	164	145	610	390	233	198	821

Percentage of Sample Retained by each Screen

	Test No. 3	Date 9/12/94	Flow (l/s) 129.14		Test No. 4	Date 9/12/94	Flow (l/s) 101.08	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	46	29	25	94.3	45	30	25	95.5
Sanitary towels	100	0	0	5.7	100	0	0	4.5
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	49	27	24	100	48	28	24	100

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	9/12/94	105.26		6	9/12/94	101.38	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	414	270	168	852	330	113	75	518
Sanitary towels	38	0	0	38	188	0	0	188
Tampons	43	0	0	43	36	0	0	36
TOTAL	495	270	168	933	554	113	75	742

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	9/12/94	105.26		6	9/12/94	101.38	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	49	32	20	91.3	64	22	14	69.8
Sanitary towels	100	0	0	4.1	100	0	0	25.3
Tampons	100	0	0	4.6	100	0	0	4.9
TOTAL	53	29	18	100	75	15	10	100

Long Lane Sewage Treatment Works

Testing of a 6.0 mm Square Staggered Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	9/12/94	94.74		8	9/12/94	90.79	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	369	216	200	785	285	231	175	691
Sanitary towels	162	0	0	162	88	0	0	88
Tampons	53	0	0	53	0	0	0	0
TOTAL	584	216	200	1000	373	231	175	779

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	9/12/94	94.74		8	9/12/94	90.79	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	47	28	25	78.5	41	33	25	88.7
Sanitary towels	100	0	0	16.2	100	0	0	11.3
Tampons	100	0	0	5.3	0	0	0	0.0
TOTAL	58	22	20	100	48	30	22	100

COPASACS (PLASTIC MESH)

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
31/10/94	1	79.57	410	270	220	*
31/10/94	2	99.56	360	220	190	*
31/10/94	3	73.25	660	440	230	*
31/10/94	4	85.57	680	440	340	*
31/10/94	5	90.90	790	470	370	*
31/10/94	6	83.56	630	400	310	*
1/11/94	1	62.58	460	340	270	140
1/11/94	2	66.08	740	480	380	150
1/11/94	3	63.93	620	450	340	170
1/11/94	4	61.76	510	350	270	100
1/11/94	5	69.43	690	480	360	140
1/11/94	6	79.61	580	380	300	130
1/11/94	7	67.66	830	520	400	160
1/11/94	8	63.97	660	500	350	140
7/11/94	1	?	620	440	350	200
7/11/94	2	?	740	520	410	210
7/11/94	3	?	760	530	420	240
7/11/94	4	?	610	460	390	280
7/11/94	5	?	550	420	350	200
7/11/94	6	?	570	450	360	210
8/11/94	1	?	650	490	400	210
8/11/94	2	?	670	430	360	160
8/11/94	3	?	610	450	310	150
8/11/94	4	?	510	340	260	130
8/11/94	5	?	610	410	300	140
8/11/94	6	?	690	480	370	170
8/11/94	7	?	720	470	360	160
8/11/94	8	?	520	370	290	140

Note

* No depth measurements were taken downstream of the screens on 31/10/94

? No flow data available for 7/11/94 and 8/11/94 due to blockage of the hole underneath the flow monitor transducer head (Mean Flow through 6.0 mm Copasac is 75 l/s)

COPASACS (PLASTIC MESH)

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
31/10/94	1	79.57	140	50	*	*
31/10/94	2	99.56	140	30	*	*
31/10/94	3	73.25	220	210	*	*
31/10/94	4	85.57	240	100	*	*
31/10/94	5	90.90	320	100	*	*
31/10/94	6	83.56	230	90	*	*
1/11/94	1	62.58	120	70	130	320
1/11/94	2	66.08	260	100	230	590
1/11/94	3	63.93	170	110	170	450
1/11/94	4	61.76	160	80	170	410
1/11/94	5	69.43	210	120	220	550
1/11/94	6	79.61	200	80	170	450
1/11/94	7	67.66	310	120	240	670
1/11/94	8	63.97	160	150	210	520
7/11/94	1	?	180	90	150	420
7/11/94	2	?	220	110	200	530
7/11/94	3	?	230	110	180	520
7/11/94	4	?	150	70	110	330
7/11/94	5	?	130	70	150	350
7/11/94	6	?	120	90	150	360
8/11/94	1	?	160	90	190	440
8/11/94	2	?	240	70	200	510
8/11/94	3	?	160	140	160	460
8/11/94	4	?	170	80	130	380
8/11/94	5	?	200	110	160	470
8/11/94	6	?	210	110	200	520
8/11/94	7	?	250	110	200	560
8/11/94	8	?	150	80	150	380

Note

* No depth measurements were taken downstream of the screens on 31/10/94

? No flow data available for 7/11/94 and 8/11/94 due to blockage of the hole underneath the flow monitor transducer head (Mean Flow through 6.0 mm Copasac is 75 l/s)

6.0 mm Round Perforated Polyurethane

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
28/2/95	1	97.70	800	700	650	300
28/2/95	2	115.42	420	360	280	140
28/2/95	3	81.54	510	420	330	190
28/2/95	4	95.98	410	280	220	100
28/2/95	5	76.16	460	310	260	140
28/2/95	6	95.15	500	370	300	190
28/2/95	7	92.91	480	360	300	170
28/2/95	8	60.22	540	410	340	170
28/2/95	9	98.12	750	590	460	220
28/2/95	10	86.01	450	330	280	130
7/3/95	1	116.21	410	330	260	160
7/3/95	2	186.45	380	310	240	150
7/3/95	3	139.59	560	400	340	170
7/3/95	4	66.33	470	360	290	160
7/3/95	5	150.45	470	380	250	120
7/3/95	6	77.94	590	480	380	200

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
28/2/95	1	97.70	100	50	350	500
28/2/95	2	115.42	60	80	140	280
28/2/95	3	81.54	90	90	140	320
28/2/95	4	95.98	130	60	120	310
28/2/95	5	76.16	150	50	120	320
28/2/95	6	95.15	130	70	110	310
28/2/95	7	92.91	120	60	130	310
28/2/95	8	60.22	130	70	170	370
28/2/95	9	98.12	160	130	240	530
28/2/95	10	86.01	120	50	150	320
7/3/95	1	116.21	80	70	100	250
7/3/95	2	186.45	70	70	90	230
7/3/95	3	139.59	160	60	170	390
7/3/95	4	66.33	110	70	130	310
7/3/95	5	150.45	90	130	130	350
7/3/95	6	77.94	110	100	180	390

6.4 mm Round Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
22/11/94	1	82.43	680	500	390	180
22/11/94	2	78.42	470	340	250	140
22/11/94	3	78.50	540	380	300	140
22/11/94	4	71.82	550	440	310	150
22/11/94	5	83.16	550	400	280	150
22/11/94	6	66.30	500	390	260	150
28/11/94	1	70.93	620	440	350	170
28/11/94	2	92.45	460	450	240	130
28/11/94	3	83.44	450	350	250	120
28/11/94	4	89.80	390	300	220	110
28/11/94	5	70.72	620	470	360	160
28/11/94	6	81.15	460	320	250	120
28/11/94	7	81.46	450	330	250	200
28/11/94	8	85.38	500	340	280	140

Head Losses

Date	Test Number	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
22/11/94	1	82.43	180	110	210	500
22/11/94	2	78.42	130	90	110	330
22/11/94	3	78.50	160	80	160	400
22/11/94	4	71.82	110	130	160	400
22/11/94	5	83.16	150	120	130	400
22/11/94	6	66.30	110	130	110	350
28/11/94	1	70.93	180	90	180	450
28/11/94	2	92.45	10	210	110	330
28/11/94	3	83.44	100	100	130	330
28/11/94	4	89.80	90	80	110	280
28/11/94	5	70.72	150	110	200	460
28/11/94	6	81.15	140	70	130	340
28/11/94	7	81.46	120	80	50	250
28/11/94	8	85.38	160	60	140	360

6.0 mm Square Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
12/12/94	1	78.36	340	260	210	190
12/12/94	2	109.04	420	290	220	110
12/12/94	3	84.49	360	290	240	130
12/12/94	4	93.81	500	340	260	140
12/12/94	5	105.38	490	350	290	150
12/12/94	6	96.00	420	320	250	140
12/12/94	7	88.05	420	290	260	120
12/12/94	8	76.91	530	380	300	150
12/12/94	9	74.91	490	370	300	150
12/12/94	10	76.37	470	370	290	200
12/12/94	11	63.46	400	290	230	160
12/12/94	12	71.45	410	300	230	100
12/12/94	13	72.41	380	280	220	190
12/12/94	14	66.04	470	350	290	150
12/12/94	15	86.08	390	280	210	100
12/12/94	16	61.67	580	450	360	180

Head Losses

Date	Test Number	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
12/12/94	1	78.36	80	50	20	150
12/12/94	2	109.04	130	70	110	310
12/12/94	3	84.49	70	50	110	230
12/12/94	4	93.81	160	80	120	360
12/12/94	5	105.38	140	60	140	340
12/12/94	6	96.00	100	70	110	280
12/12/94	7	88.05	130	30	140	300
12/12/94	8	76.91	150	80	150	380
12/12/94	9	74.91	120	70	150	340
12/12/94	10	76.37	100	80	90	270
12/12/94	11	63.46	110	60	70	240
12/12/94	12	71.45	110	70	130	310
12/12/94	13	72.41	100	60	30	190
12/12/94	14	66.04	120	60	140	320
12/12/94	15	86.08	110	70	110	290
12/12/94	16	61.67	130	90	180	400

6 mm Staggered Square Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
12/02/94	1	77.66	450	330	260	120
12/02/94	2	76.75	630	540	430	270
12/02/94	3	50.41	480	370	270	140
12/02/94	4	76.41	420	340	260	170
12/02/94	5	65.40	480	400	360	230
12/02/94	6	75.81	450	360	280	170
12/09/94	1	100.84	480	380	290	170
12/09/94	2	101.42	560	400	360	160
12/09/94	3	129.14	410	350	250	140
12/09/94	4	101.08	550	410	320	160
12/09/94	5	105.26	530	390	300	150
12/09/94	6	101.38	410	330	280	170
12/09/94	7	94.74	550	410	310	200
12/09/94	8	90.79	560	460	370	250

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
12/02/94	1	77.66	120	70	140	330
12/02/94	2	76.75	90	110	160	360
12/02/94	3	50.41	110	100	130	340
12/02/94	4	76.41	80	80	90	250
12/02/94	5	65.40	80	40	130	250
12/02/94	6	75.81	90	80	110	280
12/09/94	1	100.84	100	90	120	310
12/09/94	2	101.42	160	40	200	400
12/09/94	3	129.14	60	100	110	270
12/09/94	4	101.08	140	90	160	390
12/09/94	5	105.26	140	90	150	380
12/09/94	6	101.38	80	50	110	240
12/09/94	7	94.74	140	100	110	350
12/09/94	8	90.79	100	90	120	310

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/02/94	69.78		2	11/02/94	71.14	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	650	350	325	1325	725	425	250	1400
Sanitary towels	100	0	0	100	10	0	0	10
Tampons	0	0	0	0	50	0	0	50
TOTAL	750	350	325	1425	785	425	250	1460

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	11/02/94	69.78		2	11/02/94	71.14	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	49	26	25	93.0	52	30	18	95.9
Sanitary towels	100	0	0	7.0	100	0	0	0.7
Tampons	0	0	0	0.0	100	0	0	3.4
TOTAL	53	24	23	100	54	29	17	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/02/94	62.98		4	11/02/94	68.79	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	650	350	300	1300	675	350	325	1350
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	650	350	300	1300	675	350	325	1350

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	11/02/94	62.98		4	2/11/*94	68.79	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	50	27	23	100.0	50	26	24	100.0
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	50	27	23	100	50	26	24	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/02/94	71.13		1	17/11/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	60	0	0	60
F Paper, Veg & Faeces	550	325	300	1175	432	348	285	1065
Sanitary towels	50	0	0	50	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	600	325	300	1225	492	348	285	1125

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	11/02/94	71.13		1	17/11/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	5.3
F Paper, Veg & Faeces	47	28	26	95.9	41	33	27	94.7
Sanitary towels	100	0	0	4.1	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	49	27	24	100	44	31	25	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	2	17/11/94	?		3	17/11/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	557	339	323	1219	620	319	319	1258
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	557	339	323	1219	620	319	319	1258

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	2	17/11/94	?		3	17/11/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	46	28	26	100.0	50	25	25	100.0
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	46	28	26	100	50	25	25	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	4	17/11/94	?		5	17/11/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	0	0	0	0
F Paper, Veg & Faeces	660	373	317	1350	647	371	335	1353
Sanitary towels	134	0	0	134	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	806	373	317	1496	647	371	335	1353

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	4	17/11/94	?		5	17/11/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.8	0	0	0	0.0
F Paper, Veg & Faeces	49	28	23	90.2	48	27	25	100.0
Sanitary towels	100	0	0	9.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	25	21	100	48	27	25	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	6	17/11/94	?		7	17/11/94	?	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	6	0	0	6
F Paper, Veg & Faeces	511	347	291	1149	491	309	285	1085
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	523	347	291	1161	497	309	285	1091

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	6	17/11/94	?		7	17/11/94	?	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.0	100	0	0	0.6
F Paper, Veg & Faeces	44	30	25	99.0	45	28	26	99.5
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	45	30	25	100	46	28	26	100

Testing of three 6mm Copasac (Plastic Mesh) Screens

Mass of Sample Collected

	Test No.	Date	Flow (l/s)	
	8	17/11/94	?	
		Screen Number		
Mass (Grams)	1	2	3	Total
Cotton Bud Sticks	0	0	0	0
F Paper, Veg & Faeces	448	283	260	991
Sanitary towels	79	0	0	79
Tampons	0	0	0	0
TOTAL	527	283	260	1070

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)	
	8	17/11/94	?	
		Screen Number		
%age of total mass (%)	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0
F Paper, Veg & Faeces	45	29	26	92.6
Sanitary towels	100	0	0	7.4
Tampons	0	0	0	0.0
TOTAL	49	27	24	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	1/3/95	115.39		2	1/3/95	118.95	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	592	423	318	1333	491	285	250	1026
Sanitary towels	11	0	0	11	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	603	423	318	1344	491	285	250	1026

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	1/3/95	115.39		2	1/3/95	118.95	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	44	32	24	99.2	48	28	24	100.0
Sanitary towels	100	0	0	0.8	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	45	31	24	100	48	28	24	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	1/3/95	116.84		4	1/3/95	99.95	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	18	0	0	18	0	0	0	0
F Paper, Veg & Faeces	417	237	179	833	477	231	194	902
Sanitary towels	0	0	0	0	35	0	0	35
Tampons	0	0	0	0	0	0	0	0
TOTAL	435	237	179	851	512	231	194	937

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	1/3/95	116.84		4	1/3/95	99.95	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	2.1	0	0	0	0.0
F Paper, Veg & Faeces	50	28	22	97.9	53	26	21	96.3
Sanitary towels	0	0	0	0.0	100	0	0	3.7
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	51	28	21	100	54	25	21	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	1/3/95	103.66		6	1/3/95	108.99	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	505	250	181	936	361	217	143	721
Sanitary towels	0	0	0	0	51	0	0	51
Tampons	0	0	0	0	0	0	0	0
TOTAL	505	250	181	936	412	217	143	772

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	1/3/95	103.66		6	1/3/95	108.99	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	54	27	19	100.0	50	30	20	93.4
Sanitary towels	0	0	0	0.0	100	0	0	6.6
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	27	19	100	53	28	19	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	8/3/95	121.98		2	8/3/95	119.03	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	218	185	148	551	288	165	177	630
Sanitary towels	0	0	0	0	19	0	0	19
Tampons	0	0	0	0	0	0	0	0
TOTAL	218	185	148	551	307	165	177	649

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	8/3/95	121.98		2	8/3/95	119.03	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	39	34	27	100.0	46	26	28	97.1
Sanitary towels	0	0	0	0.0	100	0	0	2.9
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	39	34	27	100	47	26	27	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	8/3/95	124.42		4	8/3/95	101.28	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	222	140	164	526	265	187	169	621
Sanitary towels	37	0	0	37	23	0	0	23
Tampons	0	0	0	0	0	0	0	0
TOTAL	259	140	164	563	294	187	169	650

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	8/3/95	124.42		4	8/3/95	101.28	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.9
F Paper, Veg & Faeces	42	27	31	93.4	43	30	27	95.6
Sanitary towels	100	0	0	6.6	100	0	0	3.5
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	46	25	29	100	45	29	26	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	8/3/95	121.78		6	8/3/95	114.73	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	251	194	150	595	252	144	129	525
Sanitary towels	41	0	0	41	35	0	0	35
Tampons	0	0	0	0	0	0	0	0
TOTAL	292	194	150	636	293	144	129	566

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	8/3/95	121.78		6	8/3/95	114.73	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.1
F Paper, Veg & Faeces	42	33	25	93.6	48	27	25	92.7
Sanitary towels	100	0	0	6.4	100	0	0	6.2
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	46	30	24	100	52	25	23	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	8/3/95	120.80		8	8/3/95	115.83	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	210	152	130	492	211	122	123	456
Sanitary towels	19	0	0	19	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	229	152	130	511	217	122	123	462

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	8/3/95	120.80		8	8/3/95	115.83	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.3
F Paper, Veg & Faeces	43	31	26	96.3	46	27	27	98.7
Sanitary towels	100	0	0	3.7	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	45	30	25	100	47	26	27	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	23/11/94	86.33		2	23/11/94	65.26	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	801	360	314	1475	917	365	341	1623
Sanitary towels	0	0	0	0	85	0	0	85
Tampons	0	0	0	0	0	0	0	0
TOTAL	801	360	314	1475	1002	365	341	1708

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	23/11/94	86.33		2	23/11/94	65.26	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	54	24	21	100.0	57	22	21	95.0
Sanitary towels	0	0	0	0.0	100	0	0	5.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	25	21	100	59	21	20	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	23/11/94	69.12		4	23/11/94	71.13	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	654	352	288	1294	707	309	285	1301
Sanitary towels	75	0	0	75	82	0	0	82
Tampons	0	0	0	0	0	0	0	0
TOTAL	729	352	288	1369	795	309	285	1389

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	23/11/94	69.12		4	23/11/94	71.13	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.4
F Paper, Veg & Faeces	51	27	22	94.5	54	24	22	93.7
Sanitary towels	100	0	0	5.5	100	0	0	5.9
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	53	26	21	100	57	22	21	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	23/11/94	74.88		6	23/11/94	64.11	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	610	309	207	1126	422	252	212	886
Sanitary towels	0	0	0	0	66	0	0	66
Tampons	0	0	0	0	0	0	0	0
TOTAL	610	309	207	1126	488	252	212	952

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	23/11/94	74.88		6	23/11/94	64.11	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	54	27	18	100.0	48	28	24	93.1
Sanitary towels	0	0	0	0.0	100	0	0	6.9
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	28	18	100	51	27	22	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No. 1	Date 24/11/94	Flow (l/s) 85.73		Test No. 2	Date 24/11/94	Flow (l/s) 58.88	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	6	0	0	6
F Paper, Veg & Faeces	794	367	241	1402	755	315	182	1252
Sanitary towels	45	0	0	45	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	845	367	241	1453	761	315	182	1258

Percentage of Sample Retained by each Screen

	Test No. 1	Date 24/11/94	Flow (l/s) 85.73		Test No. 2	Date 24/11/94	Flow (l/s) 58.88	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.4	100	0	0	0.5
F Paper, Veg & Faeces	57	26	17	96.5	60	25	15	99.5
Sanitary towels	100	0	0	3.1	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	58	25	17	100	61	25	14	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	24/11/94	69.33		4	24/11/94	87.05	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	0	0	0	0
F Paper, Veg & Faeces	1056	352	294	1702	868	334	245	1447
Sanitary towels	61	0	0	61	24	0	0	24
Tampons	0	0	0	0	0	0	0	0
TOTAL	1123	352	294	1769	892	334	245	1471

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	24/11/94	69.33		4	24/11/94	87.05	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.3	0	0	0	0.0
F Paper, Veg & Faeces	62	21	17	96.2	60	23	17	98.4
Sanitary towels	100	0	0	3.4	100	0	0	1.6
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	63	20	17	100	60	23	17	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	24/11/94	89.22		6	24/11/94	81.06	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	699	303	204	1206	724	266	234	1224
Sanitary towels	0	0	0	0	43	0	0	43
Tampons	0	0	0	0	0	0	0	0
TOTAL	699	303	204	1206	767	266	234	1267

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	24/11/94	89.22		6	24/11/94	81.06	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	58	25	17	100.0	59	22	19	96.6
Sanitary towels	0	0	0	0.0	100	0	0	3.4
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	58	25	17	100	61	21	18	100

Testing of a 6.4 mm Round Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	24/11/94	79.84		8	24/11/94	81.79	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	514	236	192	942	537	243	152	932
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	514	236	192	942	537	243	152	932

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	24/11/94	79.84		8	24/11/94	81.79	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	55	25	20	100.0	58	26	16	100.0
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	55	25	20	100	58	26	16	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	15/12/94	63.32		2	15/12/94	51.98	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	565	355	291	1211	550	340	267	1157
Sanitary towels	18	0	0	18	31	0	0	31
Tampons	0	0	0	0	0	0	0	0
TOTAL	583	355	291	1229	581	340	267	1188

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	15/12/94	63.32		2	15/12/94	51.98	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	47	29	24	98.5	48	29	23	97.4
Sanitary towels	100	0	0	1.5	100	0	0	2.6
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	47	29	24	100	49	29	22	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	15/12/94	56.43		4	15/12/94	74.64	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	404	333	203	940	517	267	234	1018
Sanitary towels	0	0	0	0	33	0	0	33
Tampons	61	0	0	61	0	0	0	0
TOTAL	465	333	203	1001	550	267	234	1051

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	15/12/94	56.43		4	15/12/94	74.64	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	43	35	22	93.9	51	26	23	96.9
Sanitary towels	0	0	0	0.0	100	0	0	3.1
Tampons	100	0	0	6.1	0	0	0	0.0
TOTAL	46	33	20	100	52	25	22	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	15/12/94	70.44		6	15/12/94	68.01	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	12	0	0	12
F Paper, Veg & Faeces	603	294	224	1121	570	255	220	1045
Sanitary towels	0	0	0	0	23	0	0	23
Tampons	0	0	0	0	0	0	0	0
TOTAL	603	294	224	1121	605	255	220	1080

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	15/12/94	70.44		6	15/12/94	68.01	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.1
F Paper, Veg & Faeces	54	26	20	100.0	55	24	21	96.8
Sanitary towels	0	0	0	0.0	100	0	0	2.1
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	54	26	20	100	56	24	20	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	15/12/94	57.30		8	15/12/94	77.16	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	568	290	253	1111	417	256	185	858
Sanitary towels	47	0	0	47	17	0	0	17
Tampons	0	0	0	0	0	0	0	0
TOTAL	615	290	253	1158	440	256	185	881

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	15/12/94	57.30		8	15/12/94	77.16	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.7
F Paper, Veg & Faeces	51	26	23	95.9	49	30	22	97.4
Sanitary towels	100	0	0	4.1	100	0	0	1.9
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	53	25	22	100	50	29	21	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	15/12/94	63.92		10	15/12/94	48.80	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	12	0	0	12
F Paper, Veg & Faeces	452	245	219	916	546	290	193	1029
Sanitary towels	108	0	0	108	11	0	0	11
Tampons	0	0	0	0	0	0	0	0
TOTAL	560	245	219	1024	569	290	193	1052

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	9	15/12/94	63.92		10	15/12/94	48.80	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	1.1
F Paper, Veg & Faeces	49	27	24	89.5	53	28	19	97.8
Sanitary towels	100	0	0	10.5	100	0	0	1.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	55	24	21	100	54	28	18	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	11	15/12/94	52.04		12	15/12/94	57.19	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	609	228	202	1039	456	236	207	899
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	35	0	0	35	0	0	0	0
TOTAL	644	228	202	1074	456	236	207	899

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	11	15/12/94	52.04		12	15/12/94	57.19	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	59	22	19	96.7	51	26	23	100.0
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	100	0	0	3.3	0	0	0	0.0
TOTAL	60	21	19	100	51	26	23	100

Testing of a 6 mm Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	13	15/12/94	59.37		14	15/12/94	48.64	
	Screen Number				Screen Number			
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	342	229	178	749	475	250	208	933
Sanitary towels	21	0	0	21	40	0	0	40
Tampons	0	0	0	0	67	0	0	67
TOTAL	363	229	178	770	582	250	208	1040

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	13	15/12/94	59.37		14	15/12/94	48.64	
	Screen Number				Screen Number			
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	46	31	24	97.3	51	27	22	89.7
Sanitary towels	100	0	0	2.7	100	0	0	3.8
Tampons	0	0	0	0.0	100	0	0	6.4
TOTAL	47	30	23	100	56	24	20	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No. 1	Date 30/11/94	Flow (l/s) 45.96		Test No. 2	Date 30/11/94	Flow (l/s) 48.42	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	520	320	229	1069	292	478	246	1016
Sanitary towels	44	0	0	44	53	0	0	53
Tampons	0	0	0	0	0	0	0	0
TOTAL	564	320	229	1113	345	478	246	1069

Percentage of Sample Retained by each Screen

	Test No. 1	Date 30/11/94	Flow (l/s) 45.96		Test No. 2	Date 30/11/94	Flow (l/s) 48.42	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	49	30	21	96.0	29	47	24	95.0
Sanitary towels	100	0	0	4.0	100	0	0	5.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	51	29	20	100	32	45	23	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	30/11/94	36.40		4	30/11/94	62.01	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	513	375	248	1136	419	282	178	879
Sanitary towels	0	0	0	0	47	0	0	47
Tampons	0	0	0	0	0	0	0	0
TOTAL	513	375	248	1136	466	282	178	926

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	30/11/94	36.40		4	30/11/94	62.01	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	45	33	22	100.0	48	32	20	94.9
Sanitary towels	0	0	0	0.0	100	0	0	5.1
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	45	33	22	100	50	31	19	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	30/11/94	59.66		6	30/11/94	46.70	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	684	337	219	1240	525	309	211	1045
Sanitary towels	76	0	0	76	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	760	337	219	1316	525	309	211	1045

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	30/11/94	59.66		6	30/11/94	46.70	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	55	27	18	94.2	50	30	20	100.0
Sanitary towels	100	0	0	5.8	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	58	25	17	100	50	30	20	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No. 7	Date 30/11/94	Flow (l/s) 61.91		Test No. 8	Date 30/11/94	Flow (l/s) 54.42	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	6	0	0	6
F Paper, Veg & Faeces	399	293	180	872	312	382	148	842
Sanitary towels	31	0	0	31	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	430	293	180	903	318	382	148	848

Percentage of Sample Retained by each Screen

	Test No. 7	Date 30/11/94	Flow (l/s) 61.91		Test No. 8	Date 30/11/94	Flow (l/s) 54.42	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	100	0	0	0.7
F Paper, Veg & Faeces	46	34	21	96.6	37	45	18	99.3
Sanitary towels	100	0	0	3.4	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	48	32	20	100	38	45	17	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	1/12/94	71.33		2	1/12/94	56.74	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	12	0	0	12	0	0	0	0
F Paper, Veg & Faeces	356	303	220	879	659	400	245	1304
Sanitary towels	48	0	0	48	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	416	303	220	939	659	400	245	1304

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	1	1/12/94	71.33		2	1/12/94	56.74	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	1.3	0	0	0	0.0
F Paper, Veg & Faeces	41	34	25	93.6	51	31	19	100.0
Sanitary towels	100	0	0	5.1	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	44	32	24	100	50	31	19	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	1/12/94	50.15		4	1/12/94	49.40	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	613	273	158	1044	639	275	219	1133
Sanitary towels	0	0	0	0	77	0	0	77
Tampons	37	0	0	37	0	0	0	0
TOTAL	650	273	158	1081	716	275	219	1210

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	3	1/12/94	50.15		4	1/12/94	49.40	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	59	26	15	96.6	56	24	19	93.6
Sanitary towels	0	0	0	0.0	100	0	0	6.4
Tampons	100	0	0	3.4	0	0	0	0.0
TOTAL	60	25	15	100	59	23	18	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	1/12/94	46.83		6	1/12/94	45.48	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	0	0	0	0	0	0	0	0
F Paper, Veg & Faeces	333	261	212	806	608	425	235	1268
Sanitary towels	0	0	0	0	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	333	261	212	806	608	425	235	1268

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	5	1/12/94	46.83		6	1/12/94	45.48	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	0	0	0	0.0	0	0	0	0.0
F Paper, Veg & Faeces	41	32	26	100.0	48	34	19	100.0
Sanitary towels	0	0	0	0.0	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	41	33	26	100	48	33	19	100

Testing of a 6 mm Staggered Square Perforated Steel Sheet

Mass of Sample Collected

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	1/12/94	59.26		8	1/12/94	59.69	
	Screen	Number			Screen	Number		
Mass (Grams)	1	2	3	Total	1	2	3	Total
Cotton Bud Sticks	6	0	0	6	0	0	0	0
F Paper, Veg & Faeces	433	266	176	875	501	311	198	1010
Sanitary towels	58	0	0	58	0	0	0	0
Tampons	0	0	0	0	0	0	0	0
TOTAL	497	266	176	939	501	311	198	1010

Percentage of Sample Retained by each Screen

	Test No.	Date	Flow (l/s)		Test No.	Date	Flow (l/s)	
	7	1/12/94	59.26		8	1/12/94	59.69	
	Screen	Number			Screen	Number		
%age of total mass (%)	1	2	3	% Sample	1	2	3	% Sample
Cotton Bud Sticks	100	0	0	0.6	0	0	0	0.0
F Paper, Veg & Faeces	49	30	20	93.2	50	31	20	100.0
Sanitary towels	100	0	0	6.2	0	0	0	0.0
Tampons	0	0	0	0.0	0	0	0	0.0
TOTAL	53	28	19	100	50	31	19	100

COPASACS

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
2/11/94	1	69.78	480	310	280	200
2/11/94	2	71.14	480	340	260	230
2/11/94	3	62.98	470	330	260	210
2/11/94	4	68.79	470	330	270	220
2/11/94	5	71.13	450	300	260	220
17/11/94	1	?	500	410	360	360
17/11/94	2	?	535	430	370	340
17/11/94	3	?	540	440	420	400
17/11/94	4	?	530	430	410	370
17/11/94	5	?	530	470	470	460
17/11/94	6	?	550	450	450	430
17/11/94	7	?	530	490	420	400
17/11/94	8	?	610	480	480	460

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
2/11/94	1	69.78	170	30	80	280
2/11/94	2	71.14	140	80	30	250
2/11/94	3	62.98	140	70	50	260
2/11/94	4	68.79	140	60	50	250
2/11/94	5	71.13	150	40	40	230
17/11/94	1	?	90	50	0	140
17/11/94	2	?	105	60	30	195
17/11/94	3	?	100	20	20	140
17/11/94	4	?	100	20	40	160
17/11/94	5	?	60	0	10	70
17/11/94	6	?	100	0	20	120
17/11/94	7	?	40	70	20	130
17/11/94	8	?	130	0	20	150

? No flow data available for 17/11/94 due to blockage of the hole underneath the flow monitor transducer head (Mean Flow through 6.0 mm Copasac is 69 l/s)

Head Loss

6.0 mm Round Perforated Polyurethane Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
1/3/95	1	115.39	550	440	440	440
1/3/95	2	118.95	570	500	490	480
1/3/95	3	116.84	530	470	470	470
1/3/95	4	99.95	550	480	470	440
1/3/95	5	103.66	550	480	430	430
1/3/95	6	108.99	560	530	500	500
8/3/95	1	121.98	390	340	300	280
8/3/95	2	119.03	400	330	300	250
8/3/95	3	124.42	380	320	320	290
8/3/95	4	101.28	380	320	310	270
8/3/95	5	121.78	380	330	290	250
8/3/95	6	114.73	380	320	280	270
8/3/95	7	120.80	360	320	290	280
8/3/95	8	115.83	360	320	310	280

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
1/3/95	1	115.39	110	0	0	110
1/3/95	2	118.95	70	10	10	90
1/3/95	3	116.84	60	0	0	60
1/3/95	4	99.95	70	10	30	110
1/3/95	5	103.66	70	50	0	120
1/3/95	6	108.99	30	30	0	60
8/3/95	1	121.98	50	40	20	110
8/3/95	2	119.03	70	30	50	150
8/3/95	3	124.42	60	0	30	90
8/3/95	4	101.28	60	10	40	110
8/3/95	5	121.78	50	40	40	130
8/3/95	6	114.73	60	40	10	110
8/3/95	7	120.80	40	30	10	80
8/3/95	8	115.83	40	10	30	80

6.4 mm Round Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
23/11/94	1	86.33	500	490	490	400
23/11/94	2	65.26	510	450	400	380
23/11/94	3	69.12	510	450	390	350
23/11/95	4	71.13	520	470	440	410
23/11/96	5	74.88	510	440	420	350
23/11/97	6	64.11	470	450	400	380
24/11/94	1	85.73	500	480	420	380
24/11/94	2	58.88	510	440	430	410
24/11/94	3	69.33	540	460	280	230
24/11/94	4	87.05	500	460	430	390
24/11/94	5	89.22	490	450	420	400
24/11/94	6	81.06	540	470	460	440
24/11/94	7	79.84	490	450	410	390
24/11/94	8	81.79	450	400	360	330

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
23/11/94	1	86.33	10	0	90	100
23/11/94	2	65.26	60	50	20	130
23/11/94	3	69.12	60	60	40	160
23/11/95	4	71.13	50	30	30	110
23/11/96	5	74.88	70	20	70	160
23/11/97	6	64.11	20	50	20	90
24/11/94	1	85.73	20	60	40	120
24/11/94	2	58.88	70	10	20	100
24/11/94	3	69.33	80	180	50	310
24/11/94	4	87.05	40	30	40	110
24/11/94	5	89.22	40	30	20	90
24/11/94	6	81.06	70	10	20	100
24/11/94	7	79.84	40	40	20	100
24/11/94	8	81.79	50	40	30	120

6.0 mm Square Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
15/12/94	1	63.32	580	500	460	450
15/12/94	2	51.98	570	540	500	490
15/12/94	3	56.43	600	570	550	540
15/12/94	4	74.64	610	530	520	500
15/12/94	5	70.44	620	500	440	420
15/12/94	6	68.01	590	480	470	450
15/12/94	7	57.30	580	480	470	450
15/12/94	8	77.16	580	510	500	490
15/12/94	9	63.92	570	500	490	480
15/12/94	10	48.80	550	470	470	450
15/12/94	11	52.04	530	490	480	460
15/12/94	12	57.19	540	450	420	400
15/12/94	13	59.37	530	490	470	450
15/12/94	14	48.64	520	500	470	460

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
15/12/94	1	63.32	80	40	10	130
15/12/94	2	51.98	30	40	10	80
15/12/94	3	56.43	30	20	10	60
15/12/94	4	74.64	80	10	20	110
15/12/94	5	70.44	120	60	20	200
15/12/94	6	68.01	110	10	20	140
15/12/94	7	57.30	100	10	20	130
15/12/94	8	77.16	70	10	10	90
15/12/94	9	63.92	70	10	10	90
15/12/94	10	48.80	80	0	20	100
15/12/94	11	52.04	40	10	20	70
15/12/94	12	57.19	90	30	20	140
15/12/94	13	59.37	40	20	20	80
15/12/94	14	48.64	20	30	10	60

Holbrook Sewage Treatment Works

Head Loss

6 mm Square Staggered Perforated Steel Sheet

Actual Depth Measurements

Date	Test No.	Flow (l/s)	Position of Depth Measurement			
			Upstream of Screens (mm)	Between Screens 1 & 2 (mm)	Between Screens 2 & 3 (mm)	Downstream of Screens (mm)
30/11/94	1	45.96	440	380	320	260
30/11/94	2	48.42	490	470	320	250
30/11/94	3	36.40	480	300	260	220
30/11/94	4	62.01	450	340	300	260
30/11/94	5	59.66	460	380	320	260
30/11/94	6	46.70	470	390	320	300
30/11/94	7	61.91	490	340	330	320
30/11/94	8	54.42	380	360	350	310
12/01/94	1	71.33	440	420	350	320
12/01/94	2	56.74	480	350	350	320
12/01/94	3	50.15	480	370	360	350
12/01/94	4	49.40	450	350	290	240
12/01/94	5	46.83	420	400	390	330
12/01/94	6	45.48	480	450	260	200
12/01/94	7	59.26	450	370	310	260
12/01/94	8	59.69	450	330	260	210

Head Losses

Date	Test No.	Flow (l/s)	Head Loss (mm)			
			Head loss from Screen 1	Head loss from Screen 2	Head loss from Screen 3	Total Head Loss from All Screens
30/11/94	1	45.96	60	60	60	180
30/11/94	2	48.42	20	150	70	240
30/11/94	3	36.40	180	40	40	260
30/11/94	4	62.01	110	40	40	190
30/11/94	5	59.66	80	60	60	200
30/11/94	6	46.70	80	70	20	170
30/11/94	7	61.91	150	10	10	170
30/11/94	8	54.42	20	10	40	70
12/01/94	1	71.33	20	70	30	120
12/01/94	2	56.74	130	0	30	160
12/01/94	3	50.15	110	10	10	130
12/01/94	4	49.40	100	60	50	210
12/01/94	5	46.83	20	10	60	90
12/01/94	6	45.48	30	190	60	280
12/01/94	7	59.26	80	60	50	190
12/01/94	8	59.69	120	70	50	240

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							
Cotton Bud Stick With Cotton							
Cotton Bud Stick With Cotton							
Cotton Bud Stick Without Cotton							
Cotton Bud Stick Without Cotton							
Mini Towel (Whole)							
Mini Towel Inner	25.32	35.61	28.81	26.45	27.24	26.79	24.29
Mini Towel Shell							
Sanitary Towel (Whole)							
Sanitary Towel Inner	42.38	51.17	52.63	52.23	47.40	46.92	47.27
Sanitary Towel Shell							
Tampon - Applicator	16.16	15.32	17.06	16.36	13.78	16.56	13.82
Tampon Applicator							
Tampon - Non Applicator	14.57	15.51	15.39	14.83	15.24	17.34	14.27
Tampon - Non Applicator	14.65	15.60	13.80	15.50	14.30	15.34	12.93
Toilet Tissue 10 sheets	31.69	36.75	37.06	33.29	29.71	34.87	32.44
Toilet Tissue 5 sheets	19.47	14.40	17.53	15.53	14.84	15.74	16.17
TOTAL	164.24	184.36	182.28	174.19	162.51	173.56	161.19

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							3.86
Cotton Bud Stick With Cotton							1.18
Cotton Bud Stick With Cotton							1.18
Cotton Bud Stick Without Cotton							0.64
Cotton Bud Stick Without Cotton							0.64
Mini Towel (Whole)							27.56
Mini Towel Inner	26.72	31.28	22.80	30.63	28.39	29.77	25.75
Mini Towel Shell							5.23
Sanitary Towel (Whole)							62.01
Sanitary Towel Inner	46.96	45.40	50.04	39.31	46.10	37.94	52.31
Sanitary Towel Shell							6.20
Tampon - Applicator	11.55	13.81	13.08	15.48	11.94	17.25	16.04
Tampon Applicator							6.55
Tampon - Non Applicator	16.88	16.50	14.50	14.04	14.16	19.03	15.40
Tampon - Non Applicator	14.69	14.02	16.96	16.73	15.25	14.77	17.55
Toilet Tissue 10 sheets	31.20	33.86	30.17	34.62	34.77	39.97	33.41
Toilet Tissue 5 sheets	15.92	12.86	15.82	18.44	19.88	15.12	12.24
TOTAL	163.92	167.73	163.37	169.25	170.49	173.85	287.75

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)
Condom	3.11	3.05
Cotton Bud Stick With Cotton	1.04	0.86
Cotton Bud Stick With Cotton	1.04	0.86
Cotton Bud Stick Without Cotton	0.50	0.28
Cotton Bud Stick Without Cotton	0.50	0.28
Mini Towel (Whole)	30.85	42.32
Mini Towel Inner	26.80	34.95
Mini Towel Shell	5.33	5.27
Sanitary Towel (Whole)	55.44	51.79
Sanitary Towel Inner	44.46	47.79
Sanitary Towel Shell	5.60	6.40
Tampon - Applicator	17.47	16.78
Tampon Applicator	6.58	7.21
Tampon - Non Applicator	17.05	22.08
Tampon - Non Applicator	14.66	13.34
Toilet Tissue 10 sheets	38.27	32.62
Toilet Tissue 5 sheets	13.62	17.32
TOTAL	282.32	303.20

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	68.94	74.19	75.53	75.10	67.19	75.30	56.36
First Copasac	42.90	38.43	52.98	51.06	47.38	44.61	38.50
Second Copasac	52.06	62.37	49.66	46.69	45.19	47.60	41.73
TOTAL	163.90	174.99	178.17	172.85	159.76	167.51	136.59

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	42	40	41	43	41	43	35
First Copasac	26	21	29	29	29	26	24
Second Copasac	32	34	27	27	28	27	26
%age Lost	0	5	2	1	2	3	15
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	76.53	73.48	70.16	76.25	74.11	75.53	158.05
First Copasac	40.16	47.96	48.00	44.49	49.50	48.11	59.20
Second Copasac	36.04	39.58	40.94	39.54	43.75	42.67	54.73
TOTAL	152.73	161.02	159.10	160.28	167.36	166.31	271.98

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	47	44	43	45	43	43	55
First Copasac	24	29	29	26	29	28	21
Second Copasac	22	24	25	23	26	25	19
%age Lost	7	4	3	5	2	4	5
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm plastic mesh (Copasac) Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)
Test Screen	160.96	172.45
First Copasac	50.75	53.39
Second Copasac	66.15	66.66
TOTAL	277.86	292.50

Screen Efficiencies

Screen	Retained %	Retained %
Test Screen	57	57
First Copasac	18	18
Second Copasac	23	22
%age Lost	2	4
TOTAL	100	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							
Cotton Bud Stick With Cotton							
Cotton Bud Stick With Cotton							
Cotton Bud Stick Without Cotton							
Cotton Bud Stick Without Cotton							
Mini Towel (Whole)							
Mini Towel Inner	33.13	42.38	30.06	32.93	27.72	34.27	31.90
Mini Towel Shell							
Sanitary Towel (Whole)							
Sanitary Towel Inner	54.15	55.19	50.39	55.93	49.95	50.62	48.22
Sanitary Towel Shell							
Tampon - Applicator	16.83	17.38	20.06	17.38	22.47	23.10	16.14
Tampon Applicator							
Tampon - Non Applicator	15.45	14.65	19.34	18.34	17.98	19.05	16.80
Tampon - Non Applicator	17.15	17.86	16.35	17.59	19.94	18.15	18.03
Toilet Tissue 10 sheets	31.66	41.47	35.97	29.43	37.97	31.01	34.57
Toilet Tissue 5 sheets	17.25	13.47	16.21	15.78	18.03	15.53	18.42
TOTAL	185.62	202.40	188.38	187.38	194.06	191.73	184.08

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							3.85
Cotton Bud Stick With Cotton							1.67
Cotton Bud Stick With Cotton							1.67
Cotton Bud Stick Without Cotton							1.14
Cotton Bud Stick Without Cotton							1.14
Mini Towel (Whole)							39.23
Mini Towel Inner	30.81	33.01	29.86	29.78	31.06	32.58	28.00
Mini Towel Shell							4.74
Sanitary Towel (Whole)							57.00
Sanitary Towel Inner	48.64	50.90	56.07	45.91	53.05	52.03	47.61
Sanitary Towel Shell							6.78
Tampon - Applicator	14.77	16.85	19.83	20.25	21.22	17.98	16.60
Tampon Applicator							5.85
Tampon - Non Applicator	14.52	17.28	17.30	16.92	17.04	14.27	19.81
Tampon - Non Applicator	16.52	15.60	19.40	15.40	15.90	16.87	13.92
Toilet Tissue 10 sheets	35.93	32.74	38.13	37.92	32.20	34.85	37.73
Toilet Tissue 5 sheets	23.10	21.55	21.59	14.73	15.35	18.28	15.70
TOTAL	184.29	187.93	202.18	180.91	185.82	186.86	302.44

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)
Condom	4.29	4.40
Cotton Bud Stick With Cotton	0.87	1.72
Cotton Bud Stick With Cotton	0.87	1.72
Cotton Bud Stick Without Cotton	0.39	1.14
Cotton Bud Stick Without Cotton	0.39	1.14
Mini Towel (Whole)	41.96	35.72
Mini Towel Inner	30.60	29.47
Mini Towel Shell	5.55	5.4
Sanitary Towel (Whole)	63.45	63.90
Sanitary Towel Inner	57.21	49.84
Sanitary Towel Shell	7.12	7.11
Tampon - Applicator	15.15	14.75
Tampon Applicator	7.15	6.52
Tampon - Non Applicator	20.32	19.46
Tampon - Non Applicator	16.94	15.31
Toilet Tissue 10 sheets	30.07	37.24
Toilet Tissue 5 sheets	16.16	13.59
TOTAL	318.49	308.43

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	59.17	58.59	55.69	48.74	50.81	45.42	55.06
First Copasac	62.16	63.51	75.71	50.66	65.73	70.89	46.02
Second Copasac	61.60	56.13	47.44	51.74	55.56	63.26	53.56
TOTAL	182.93	178.23	178.84	151.14	172.10	179.57	154.64

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	32	29	30	26	26	24	30
First Copasac	33	31	40	27	34	37	25
Second Copasac	33	28	25	28	29	33	29
%age Lost	1	12	5	19	11	6	16
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	40.70	47.40	57.72	48.48	54.33	46.48	162.88
First Copasac	53.51	55.06	73.65	59.54	65.00	61.18	57.80
Second Copasac	53.46	49.70	62.43	47.63	56.12	71.73	64.04
TOTAL	147.67	152.16	193.80	155.65	175.45	179.39	284.72

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	22	25	29	27	29	25	54
First Copasac	29	29	36	33	35	33	19
Second Copasac	29	26	31	26	30	38	21
%age Lost	20	19	4	14	6	4	6
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Round Perforated Polyurethane Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)
Test Screen	159.01	169.56
First Copasac	56.51	67.82
Second Copasac	53.39	65.76
TOTAL	268.91	303.14

Screen Efficiencies

Screen	Retained %	Retained %
Test Screen	50	55
First Copasac	18	22
Second Copasac	17	21
%age Lost	16	2
TOTAL	100	100

Testing of a 6 mm Round Perforated Steel Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							
Cotton Bud Stick With Cotton							
Cotton Bud Stick With Cotton							
Cotton Bud Stick Without Cotton							
Cotton Bud Stick Without Cotton							
Mini Towel (Whole)							
Mini Towel Inner	33.97	38.89	33.17	39.34	34.92	34.28	30.28
Mini Towel Shell							
Sanitary Towel (Whole)							
Sanitary Towel Inner	62.12	63.75	62.59	59.14	61.04	58.19	55.97
Sanitary Towel Shell							
Tampon - Applicator	18.23	23.64	25.74	27.46	26.09	18.20	22.90
Tampon Applicator							
Tampon - Non Applicator	18.30	17.98	16.24	18.87	18.16	21.89	23.87
Tampon - Non Applicator	20.01	15.62	21.73	16.79	17.69	15.94	17.48
Toilet Tissue 10 sheets	48.24	46.28	44.35	41.00	42.10	42.58	44.66
Toilet Tissue 5 sheets	23.22	18.85	21.87	21.50	26.00	20.98	18.89
TOTAL	224.09	225.01	225.69	224.10	226.00	212.06	214.05

Testing of a 6 mm Round Perforated Steel Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							4.03
Cotton Bud Stick With Cotton							1.09
Cotton Bud Stick With Cotton							1.09
Cotton Bud Stick Without Cotton							0.64
Cotton Bud Stick Without Cotton							0.64
Mini Towel (Whole)							36.05
Mini Towel Inner	36.73	40.40	31.88	28.63	38.40	37.45	31.14
Mini Towel Shell							4.64
Sanitary Towel (Whole)							53.02
Sanitary Towel Inner	50.35	62.76	60.45	56.09	53.44	60.52	46.64
Sanitary Towel Shell							5.04
Tampon - Applicator	29.19	25.55	21.40	18.25	19.13	26.27	15.28
Tampon Applicator							7.02
Tampon - Non Applicator	16.74	20.93	18.33	20.00	21.54	19.23	16.97
Tampon - Non Applicator	29.27	24.40	19.10	18.69	20.43	18.39	15.86
Toilet Tissue 10 sheets	44.76	39.57	28.63	35.90	32.70	43.62	32.63
Toilet Tissue 5 sheets	18.62	17.96	21.55	19.97	18.81	18.27	17.74
TOTAL	225.66	231.57	201.34	197.53	204.45	223.75	289.52

Testing of a 6 mm Round Perforated Steel Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)
Condom	5.04	6.04
Cotton Bud Stick With Cotton	2.47	2.96
Cotton Bud Stick With Cotton	2.47	2.96
Cotton Bud Stick Without Cotton	1.86	2.20
Cotton Bud Stick Without Cotton	1.86	2.20
Mini Towel (Whole)	47.66	35.10
Mini Towel Inner	39.01	30.59
Mini Towel Shell	8.30	6.40
Sanitary Towel (Whole)	52.19	68.21
Sanitary Towel Inner	51.73	46.02
Sanitary Towel Shell	8.34	7.74
Tampon - Applicator	19.79	21.02
Tampon Applicator	6.78	10.26
Tampon - Non Applicator	17.25	17.54
Tampon - Non Applicator	19.87	16.43
Toilet Tissue 10 sheets	37.85	40.99
Toilet Tissue 5 sheets	22.66	23.45
TOTAL	345.13	340.11

Testing of a 6 mm Round Perforated Steel Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	73.26	62.00	70.07	66.03	57.51	71.70	56.43
First Copasac	62.15	71.44	53.90	52.04	74.37	72.10	62.00
Second Copasac	55.97	60.15	68.11	55.08	55.48	61.34	62.09
TOTAL	191.38	193.59	192.08	173.15	187.36	205.14	180.52

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	33	28	31	29	25	34	26
First Copasac	28	32	24	23	33	34	29
Second Copasac	25	27	30	25	25	29	29
%age Lost	15	14	15	23	17	3	16
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Round Perforated Steel Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	51.68	63.97	54.32	53.56	50.75	49.57	156.00
First Copasac	56.33	57.27	64.70	46.90	60.61	61.70	72.25
Second Copasac	50.67	50.71	46.35	52.22	70.84	60.31	55.10
TOTAL	158.68	171.95	165.37	152.68	182.20	171.58	283.35

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	23	28	27	27	25	22	54
First Copasac	25	25	32	24	30	28	25
Second Copasac	22	22	23	26	35	27	19
%age Lost	30	26	18	23	11	23	2
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Round Perforated Steel Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)
Test Screen	189.49	186.19
First Copasac	80.67	51.82
Second Copasac	70.18	57.24
TOTAL	340.34	295.25

Screen Efficiencies

Screen	Retained %	Retained %
Test Screen	55	55
First Copasac	23	15
Second Copasac	20	17
%age Lost	1	13
TOTAL	100	100

Testing of a 6 mm Square Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom	2.09	6.22	4.06				
Cotton Bud Stick With Cotton	0.47	1.99	0.68				
Cotton Bud Stick With Cotton	0.47	1.99	0.68				
Cotton Bud Stick Without Cotton	0.05	1.62	0.26				
Cotton Bud Stick Without Cotton	0.05	1.62	0.26				
Mini Towel (Whole)	35.34	51.60	44.60				
Mini Towel Inner	32.80	38.84	41.65	41.26	32.53	33.71	37.23
Mini Towel Shell	3.71	10.38	5.76				
Sanitary Towel (Whole)	63.71	127.47	62.17				
Sanitary Towel Inner	63.18	63.60	62.61	77.85	63.41	69.23	55.78
Sanitary Towel Shell	5.14	12.81	6.23				
Tampon - Applicator	23.29	37.61	28.19	13.49	12.40	15.63	17.67
Tampon Applicator		11.73	10.10		2.88		
Tampon - Non Applicator	21.64	38.25	15.24	22.61	15.71	16.19	16.93
Tampon - Non Applicator	13.02		14.49	21.95	11.38	19.60	18.93
Toilet Tissue 10 sheets	68.58	68.58	68.58	67.05	60.64	58.53	41.83
Toilet Tissue 5 sheets	31.34	59.25	12.70	29.17	32.51	42.65	43.05
TOTAL	364.88	533.56	378.26	273.38	231.46	255.54	231.42

Testing of a 6 mm Square Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							
Cotton Bud Stick With Cotton							
Cotton Bud Stick With Cotton							
Cotton Bud Stick Without Cotton							
Cotton Bud Stick Without Cotton							
Mini Towel (Whole)							
Mini Towel Inner	34.68	43.60	49.59	47.66	42.33	36.59	38.55
Mini Towel Shell							
Sanitary Towel (Whole)							
Sanitary Towel Inner	67.02	70.09	77.83	83.55	76.14	69.79	70.56
Sanitary Towel Shell							
Tampon - Applicator	25.06	18.66	23.10	16.08	15.90	17.77	21.84
Tampon Applicator							
Tampon - Non Applicator	16.26	12.18	18.57	15.73	21.95	19.27	16.65
Tampon - Non Applicator	28.74	14.29	26.36	14.49	19.36	17.82	20.89
Toilet Tissue 10 sheets	57.07	51.19	65.00	66.92	65.59	45.82	50.83
Toilet Tissue 5 sheets	36.39	33.72	32.53	40.14	23.58	26.16	28.50
TOTAL	265.22	243.73	292.98	284.57	264.85	233.22	247.82

Testing of a 6 mm Square Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)
Condom		
Cotton Bud Stick With Cotton		
Cotton Bud Stick With Cotton		
Cotton Bud Stick Without Cotton		
Cotton Bud Stick Without Cotton		
Mini Towel (Whole)		
Mini Towel Inner	39.51	33.06
Mini Towel Shell		
Sanitary Towel (Whole)		
Sanitary Towel Inner	73.10	73.59
Sanitary Towel Shell		
Tampon - Applicator	22.82	19.00
Tampon Applicator		
Tampon - Non Applicator	17.34	20.49
Tampon - Non Applicator	20.46	22.96
Toilet Tissue 10 sheets	69.40	63.76
Toilet Tissue 5 sheets	28.22	32.87
TOTAL	270.85	265.73

Testing of a 6 mm Square Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	224.52	287.59	291.49	86.58	57.02	74.10	62.19
First Copasac	44.60	42.77	35.19	92.71	84.87	81.78	68.15
Second Copasac	53.22	59.86	32.23	92.12	82.44	75.94	60.32
TOTAL	322.34	390.22	358.91	271.41	224.33	231.82	190.66

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	62	54	77	32	25	29	27
First Copasac	12	8	9	34	37	32	29
Second Copasac	15	11	9	34	36	30	26
%age Lost	12	27	5	1	3	9	18
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Square Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	73.39	72.18	97.92	67.58	67.97	70.08	68.64
First Copasac	92.71	95.70	92.90	104.36	86.53	81.24	90.29
Second Copasac	74.66	72.97	73.65	93.67	85.18	73.38	77.87
TOTAL	240.76	240.85	264.47	265.61	239.68	224.70	236.80

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	28	30	33	24	26	30	28
First Copasac	35	39	32	37	33	35	36
Second Copasac	28	30	25	33	32	31	31
%age Lost	9	1	10	7	10	4	4
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Square Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)
Test Screen	62.87	61.15
First Copasac	85.66	87.64
Second Copasac	90.03	97.61
TOTAL	238.56	246.40

Screen Efficiencies

Screen	Retained %	Retained %
Test Screen	23	23
First Copasac	32	33
Second Copasac	33	37
%age Lost	12	7
TOTAL	100	100

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							
Cotton Bud Stick With Cotton							
Cotton Bud Stick With Cotton							
Cotton Bud Stick Without Cotton							
Cotton Bud Stick Without Cotton							
Mini Towel (Whole)							
Mini Towel Inner	37.41	34.38	27.32	36.08	34.23	41.10	31.74
Mini Towel Shell							
Sanitary Towel (Whole)							
Sanitary Towel Inner	64.10	65.51	74.60	65.87	68.36	65.77	67.97
Sanitary Towel Shell							
Tampon - Applicator	19.53	22.39	25.05	23.83	19.97	16.87	16.73
Tampon Applicator							
Tampon - Non Applicator	25.07	19.23	21.52	27.56	20.24	18.62	19.27
Tampon - Non Applicator	24.88	17.27	18.68	21.62	16.76	18.48	22.67
Toilet Tissue 10 sheets	50.22	56.77	65.86	58.31	41.87	51.16	46.71
Toilet Tissue 5 sheets	27.15	28.06	28.86	24.10	16.44	34.46	21.58
TOTAL	248.36	243.61	261.89	257.37	217.87	246.46	226.67

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)	Weight (g)
Condom							6.66
Cotton Bud Stick With Cotton							3.93
Cotton Bud Stick With Cotton							3.93
Cotton Bud Stick Without Cotton							3.46
Cotton Bud Stick Without Cotton							3.46
Mini Towel (Whole)							46.60
Mini Towel Inner	36.88	37.32	39.15	44.18	40.48	47.57	39.39
Mini Towel Shell							7.17
Sanitary Towel (Whole)							73.06
Sanitary Towel Inner	57.39	57.39	59.80	59.27	65.80	57.28	51.02
Sanitary Towel Shell							7.12
Tampon - Applicator	16.57	19.72	21.92	18.69	23.05	19.93	20.02
Tampon Applicator							6.83
Tampon - Non Applicator	17.67	20.11	18.96	19.95	19.74	20.10	22.23
Tampon - Non Applicator	24.40	18.10	19.48	20.11	17.52	18.75	16.71
Toilet Tissue 10 sheets	52.38	59.62	41.93	54.14	50.94	54.08	51.56
Toilet Tissue 5 sheets	34.48	37.79	21.21	19.01	31.06	26.16	26.62
TOTAL	239.77	250.05	222.45	235.35	248.59	243.87	389.77

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of individual materials introduced into inflow

Material	Weight (g)	Weight (g)
Condom	5.82	5.11
Cotton Bud Stick With Cotton	2.64	2.25
Cotton Bud Stick With Cotton	2.64	2.25
Cotton Bud Stick Without Cotton	2.00	1.77
Cotton Bud Stick Without Cotton	2.00	1.77
Mini Towel (Whole)	44.42	48.16
Mini Towel Inner	40.61	36.60
Mini Towel Shell	7.43	8.09
Sanitary Towel (Whole)	60.19	65.90
Sanitary Towel Inner	48.38	58.18
Sanitary Towel Shell	7.06	8.26
Tampon - Applicator	18.05	17.58
Tampon Applicator	7.27	4.22
Tampon - Non Applicator	17.32	15.72
Tampon - Non Applicator	15.76	14.57
Toilet Tissue 10 sheets	56.68	50.15
Toilet Tissue 5 sheets	35.93	32.80
TOTAL	374.20	373.38

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	63.97	70.83	68.89	70.16	70.42	62.02	68.79
First Copasac	61.89	54.45	57.77	58.46	56.08	57.60	57.80
Second Copasac	71.27	53.85	46.53	61.37	62.90	54.41	58.17
TOTAL	197.13	179.13	173.19	189.99	189.40	174.03	184.76

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	26	29	26	27	32	25	30
First Copasac	25	22	22	23	26	23	25
Second Copasac	29	22	18	24	29	22	26
%age Lost	21	26	34	26	13	29	18
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)	Weight Retained (g)
Test Screen	64.15	77.92	67.05	79.14	74.23	64.44	169.81
First Copasac	59.41	59.50	72.58	54.35	61.30	53.11	99.13
Second Copasac	52.52	71.02	53.59	54.41	65.54	49.95	104.28
TOTAL	176.08	208.44	193.22	187.90	201.07	167.50	373.22

Screen Efficiencies

Screen	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %	Retained %
Test Screen	27	31	30	34	30	26	44
First Copasac	25	24	33	23	25	22	25
Second Copasac	22	28	24	23	26	20	27
%age Lost	27	17	13	20	19	31	4
TOTAL	100	100	100	100	100	100	100

Testing of a 6 mm Square Staggered Steel Perforated Screen

Weight of Material Retained on each Screen

Screen	Weight Retained (g)	Weight Retained (g)
Test Screen	195.66	195.39
First Copasac	60.13	49.27
Second Copasac	63.31	57.21
TOTAL	319.10	301.87

Screen Efficiencies

Screen	Retained %	Retained %
Test Screen	52	52
First Copasac	16	13
Second Copasac	17	15
%age Lost	15	19
TOTAL	100	100

Testing of a 6 mm plastic mesh (Copasac) Screen

Pointer Gauge Readings

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)
clean	51.1	660	661
part. blind.	50.3	664	665
clean	50.3	653	653
part. blind.	49.7	663	662
clean	50.9	660	660
part. blind.	49.9	666	665
clean	49.7	657	660
part. blind.	48.9	666	665
clean	49.7	657	660
part. blind.	48.6	662	662
clean	50.7	656	659
part. blind.	49.3	662	660
clean	49.1	654	654
part. blind.	48.3	660	660
clean	50.0	656	659
part. blind.	48.9	662	662
clean	49.4	654	655
part. blind.	48.3	662	661
clean	50.6	656	659
part. blind.	49.2	662	661
clean	49.4	655	657
part. blind.	48.3	662	660
clean	49.3	650	651
part. blind.	48.2	656	656
clean	50.6	657	660
part. blind.	50.2	666	663
clean	49.6	656	656
part. blind.	49.7	680	663
clean	50.8	652	650
part. blind.	50.2	670	656
clean	50.5	653	655
part. blind.	49.8	675	661

Testing of a 6 mm plastic mesh (Copasac) Screen

Head Loss

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)	Head Loss (mm)
clean	51.1	490	488	2
part. blind.	50.3	494	492	2
clean	50.3	483	480	3
part. blind.	49.7	493	489	4
clean	50.9	490	487	3
part. blind.	49.9	496	492	4
clean	49.7	487	487	0
part. blind.	48.9	496	492	4
clean	49.7	487	487	0
part. blind.	48.6	492	489	3
clean	50.7	486	486	0
part. blind.	49.3	492	487	5
clean	49.1	484	481	3
part. blind.	48.3	490	487	3
clean	50.0	486	486	0
part. blind.	48.9	492	489	3
clean	49.4	484	482	2
part. blind.	48.3	492	488	4
clean	50.6	486	486	0
part. blind.	49.2	492	488	4
clean	49.4	485	484	1
part. blind.	48.3	492	487	5
clean	49.3	480	478	2
part. blind.	48.2	486	483	3
clean	50.6	487	487	0
part. blind.	50.2	496	490	6
clean	49.6	486	483	3
part. blind.	49.7	510	490	20
clean	50.8	482	477	5
part. blind.	50.2	500	483	17
clean	50.5	483	482	1
part. blind.	49.8	505	488	17

Testing of a 6 mm Round Perforated Polyurethane Screen

Pointer Gauge Readings

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)
clean	49.6	686	686
part. blind.	52.1	695	692
clean	49.3	683	684
part. blind.	51.1	692	690
clean	50.7	662	665
part. blind.	50.2	676	670
clean	50.8	670	671
part. blind.	50.1	675	676
clean	50.4	663	665
part. blind.	50.0	671	670
clean	50.3	663	665
part. blind.	49.7	670	670
clean	51.1	680	681
part. blind.	50.2	686	686
clean	51.4	682	684
part. blind.	50.7	691	690
clean	49.7	690	691
part. blind.	49.5	680	680
clean	51.1	660	660
part. blind.	50.5	667	665
clean	50.6	662	662
part. blind.	49.9	671	669
clean	49.2	642	643
part. blind.	48.6	653	653
clean	50.6	667	670
part. blind.	49.2	673	673
clean	49.6	680	680
part. blind.	48.4	685	680
clean	49.6	662	663
part. blind.	49.1	671	665
clean	50.8	682	683
part. blind.	49.5	690	684

Testing of a 6 mm Round Perforated Polyurethane Screen

Head Loss

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)	Head Loss (mm)
clean	49.6	516	513	3
part. blind.	52.1	525	519	6
clean	49.3	513	511	2
part. blind.	51.1	522	517	5
clean	50.7	492	492	0
part. blind.	50.2	506	497	9
clean	50.8	500	498	2
part. blind.	50.1	505	503	2
clean	50.4	493	492	1
part. blind.	50.0	501	497	4
clean	50.3	493	492	1
part. blind.	49.7	500	497	3
clean	51.1	510	508	2
part. blind.	50.2	516	513	3
clean	51.4	512	511	1
part. blind.	50.7	521	517	4
clean	49.7	520	518	2
part. blind.	49.5	510	507	3
clean	51.1	490	487	3
part. blind.	50.5	497	492	5
clean	50.6	492	489	3
part. blind.	49.9	501	496	5
clean	49.2	472	470	2
part. blind.	48.6	483	480	3
clean	50.6	497	497	0
part. blind.	49.2	503	500	3
clean	49.6	510	507	3
part. blind.	48.4	515	507	8
clean	49.6	492	490	2
part. blind.	49.1	501	492	9
clean	50.8	512	510	2
part. blind.	49.5	520	511	9

Testing of a 6 mm Round Perforated Steel Screen

Pointer Gauge Readings

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)
clean	50.3	665	665
part. blind.	49.9	670	667
clean	50.7	671	671
part. blind.	49.4	674	672
clean	50.6	676	676
part. blind.	48.9	681	680
clean	50.0	660	662
part. blind.	49.1	661	655
clean	50.4	672	672
part. blind.	49.6	673	672
clean	50.8	671	671
part. blind.	49.8	681	680
clean	50.9	673	673
part. blind.	50.3	680	676
clean	50.6	681	681
part. blind.	49.6	685	684
clean	50.7	682	683
part. blind.	50.4	690	687
clean	50.7	695	695
part. blind.	50.0	684	679
clean	50.7	674	674
part. blind.	50.1	671	670
clean	50.9	692	693
part. blind.	50.2	700	700
clean	50.4	682	682
part. blind.	49.8	687	686
clean	48.6	682	682
part. blind.	48.4	690	686
clean	50.2	680	680
part. blind.	49.2	690	683
clean	50.2	680	680
part. blind.	49.3	686	682

Testing of a 6 mm Round Perforated Steel Screen

Head Loss

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)	Head Loss (mm)
clean	50.3	495	492	3
part. blind.	49.9	500	494	6
clean	50.7	501	498	3
part. blind.	49.4	504	499	5
clean	50.6	506	503	3
part. blind.	48.9	511	507	4
clean	50.0	490	489	1
part. blind.	49.1	491	482	9
clean	50.4	502	499	3
part. blind.	49.6	503	499	4
clean	50.8	501	498	3
part. blind.	49.8	511	507	4
clean	50.9	503	500	3
part. blind.	50.3	510	503	7
clean	50.6	511	508	3
part. blind.	49.6	515	511	4
clean	50.7	512	510	2
part. blind.	50.4	520	514	6
clean	50.7	525	522	3
part. blind.	50.0	514	506	8
clean	50.7	504	501	3
part. blind.	50.1	501	497	4
clean	50.9	522	520	2
part. blind.	50.2	530	527	3
clean	50.4	512	509	3
part. blind.	49.8	517	513	4
clean	48.6	512	509	3
part. blind.	48.4	520	513	7
clean	50.2	510	507	3
part. blind.	49.2	520	510	10
clean	50.2	510	507	3
part. blind.	49.3	516	509	7

Testing of a 6 mm Square Steel Perforated Screen

Pointer Gauge Readings

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)
clean	49.5	631	633
part. blind.	48.4	641	636
clean	49.2	675	673
part. blind.	61.4	701	692
clean	49.0	650	651
part. blind.	48.0	662	660
part. blind.	50.0	675	674
clean	49.9	663	664
part. blind.	51.0	707	701
clean	50.0	674	675
part. blind.	49.0	682	681
clean	48.4	680	682
part. blind.	48.2	686	686
clean	49.5	667	670
part. blind.	48.9	673	670
clean	50.4	674	677
part. blind.	49.3	680	680
clean	49.7	673	676
part. blind.	49.2	680	680
clean	50.5	671	673
part. blind.	49.5	674	674
clean	50.2	677	680
part. blind.	49.1	683	680
clean	50.3	671	673
part. blind.	49.0	678	680
clean	50.4	675	678
part. blind.	49.9	665	665

Testing of a 6 mm Square Steel Perforated Screen

Head Loss

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)	Head Loss (mm)
clean	49.5	461	460	1
part. blind.	48.4	471	463	8
clean	49.2	505	500	5
part. blind.	61.4	531	519	12
clean	49.0	480	478	2
part. blind.	48.0	492	487	5
part. blind.	50.0	505	501	4
clean	49.9	493	491	2
part. blind.	51.0	537	528	9
clean	50.0	504	502	2
part. blind.	49.0	512	508	4
clean	48.4	510	509	1
part. blind.	48.2	516	513	3
clean	49.5	497	497	0
part. blind.	48.9	503	497	6
clean	50.4	504	504	0
part. blind.	49.3	510	507	3
clean	49.7	503	503	0
part. blind.	49.2	510	507	3
clean	50.5	501	500	1
part. blind.	49.5	504	501	3
clean	50.2	507	507	0
part. blind.	49.1	513	507	6
clean	50.3	501	500	1
part. blind.	49.0	508	507	1
clean	50.4	505	505	0
part. blind.	49.9	495	492	3

Testing of a 6 mm Square Staggered Perforated Screen

Pointer Gauge Readings

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)
clean	49.7	666	668
part. blind.	49.6	674	674
clean	50.0	675	677
part. blind.	49.8	682	682
clean	50.1	673	675
part. blind.	50.1	682	681
clean	50.0	670	673
part. blind.	49.7	680	680
clean	51.2	680	683
part. blind.	49.1	671	671
clean	50.8	655	656
part. blind.	49.9	663	661
clean	50.3	670	671
part. blind.	49.6	675	675
clean	49.6	675	677
part. blind.	49.5	683	681
clean	49.9	664	666
part. blind.	49.9	672	670
clean	49.3	673	675
part. blind.	49.3	681	680
clean	50.5	666	669
part. blind.	50.1	673	672
clean	49.1	650	652
part. blind.	48.1	671	664
clean	49.7	667	670
part. blind.	48.6	675	666
clean	50.5	656	659
part. blind.	49.7	667	657

Testing of a 6 mm Square Staggered Perforated Screen

Head Loss

Screen	Flowrate (l/s)	Upstream Gauge (mm)	Downstream Gauge (mm)	Head Loss (mm)
part. blind.	49.6	504	501	3
clean	50.0	505	504	1
part. blind.	49.8	512	509	3
clean	50.1	503	502	1
part. blind.	50.1	512	508	4
clean	50.0	500	500	0
part. blind.	49.7	510	507	3
clean	51.2	510	510	0
part. blind.	49.1	501	498	3
clean	50.8	485	483	2
part. blind.	49.9	493	488	5
clean	50.3	500	498	2
part. blind.	49.6	505	502	3
clean	49.6	505	504	1
part. blind.	49.5	513	508	5
clean	49.9	494	493	1
part. blind.	49.9	502	497	5
clean	49.3	503	502	1
part. blind.	49.3	511	507	4
clean	50.5	496	496	0
part. blind.	50.1	503	499	4
clean	49.1	480	479	1
part. blind.	48.1	501	491	10
clean	49.7	497	497	0
part. blind.	48.6	505	493	12
clean	50.5	486	486	0
part. blind.	49.7	497	484	13

Holbrook STW

Comparison of Mean Screen Retention Efficiency for three Screen system

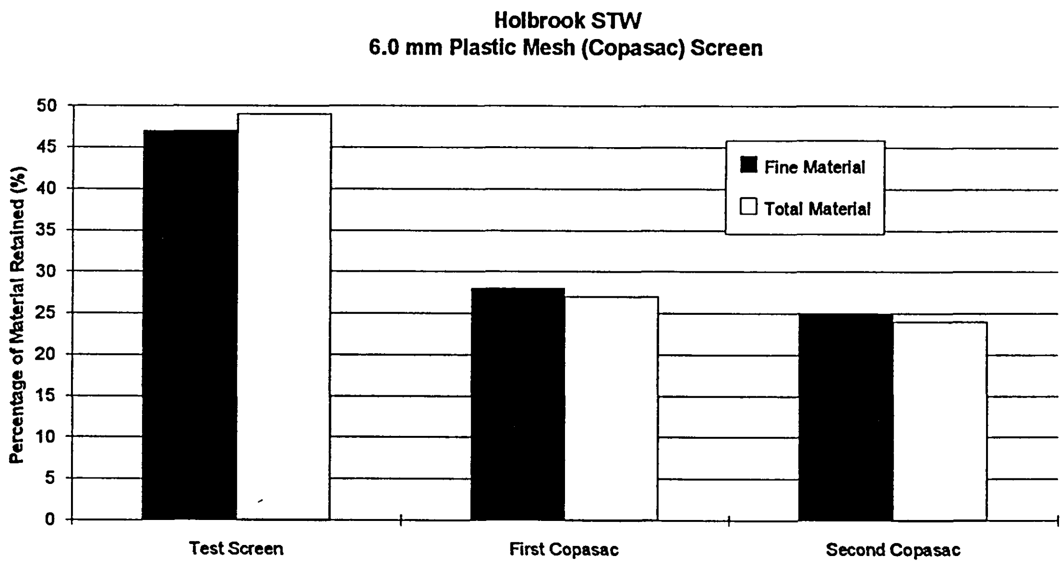


Figure D1

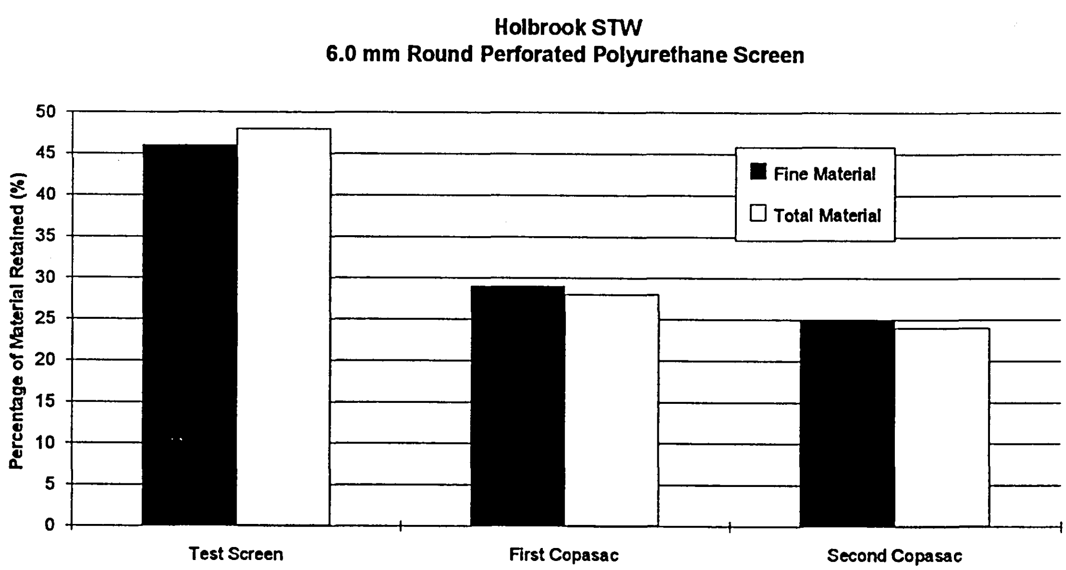


Figure D2

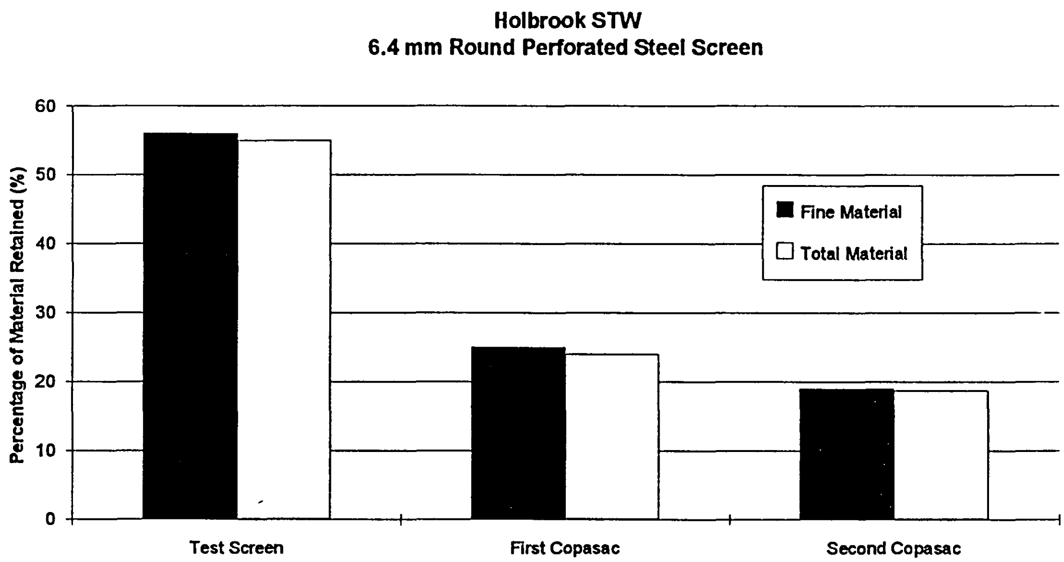


Figure D3

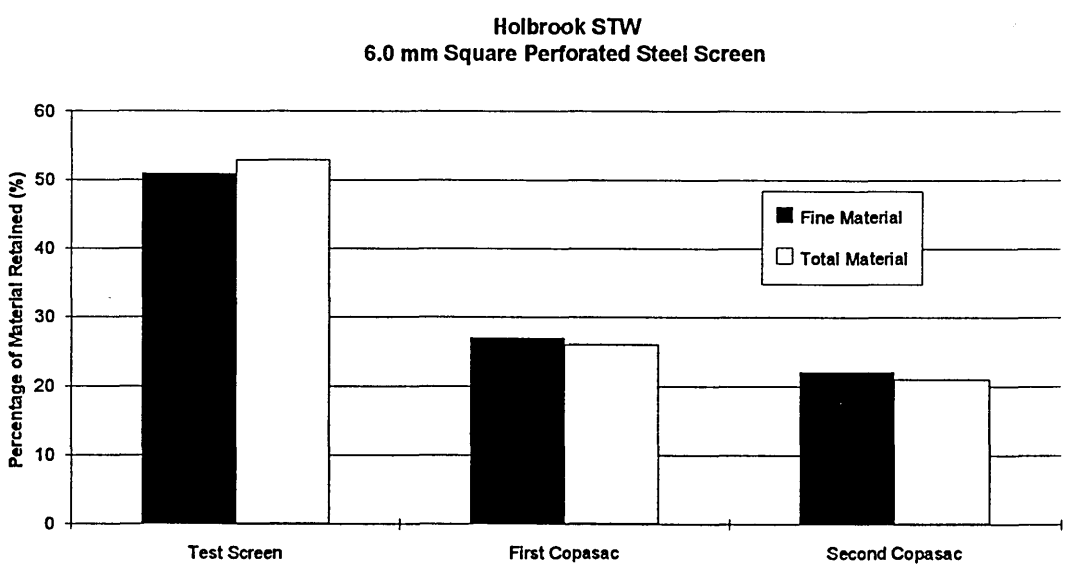
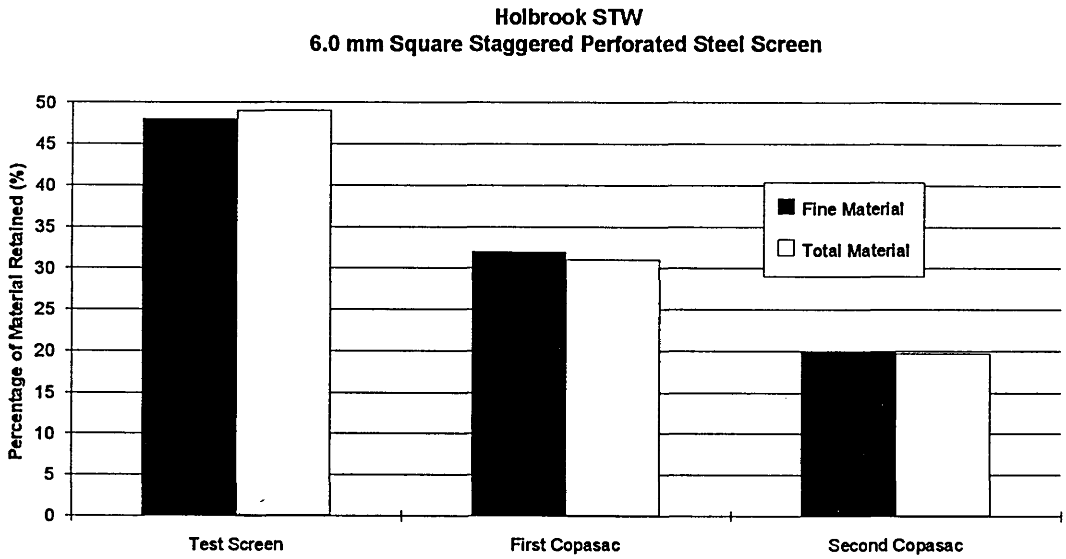


Figure D4



Holbrook STW
6.0 mm Square Staggered Perforated Steel Screen
Percentage of Material Retained (%)
50
45
40
35
30
25
20
15
10
5
0
Fine Material
Total Material
Test Screen
First Copasac
Second Copasac

Figure D5

Long Lane STW

Comparison of Mean Screen Retention Efficiency for three Screen system

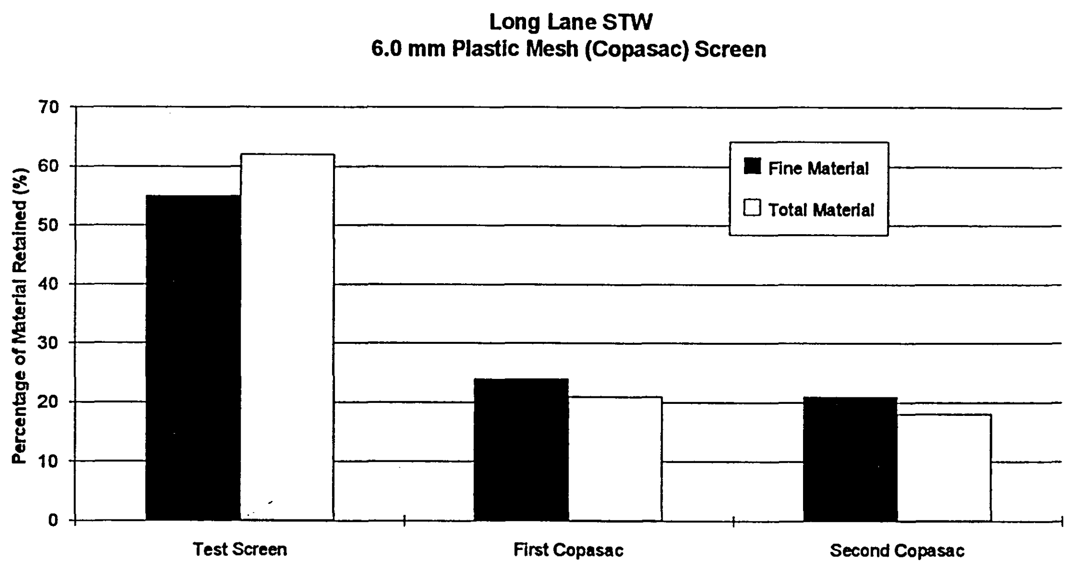


Figure D6

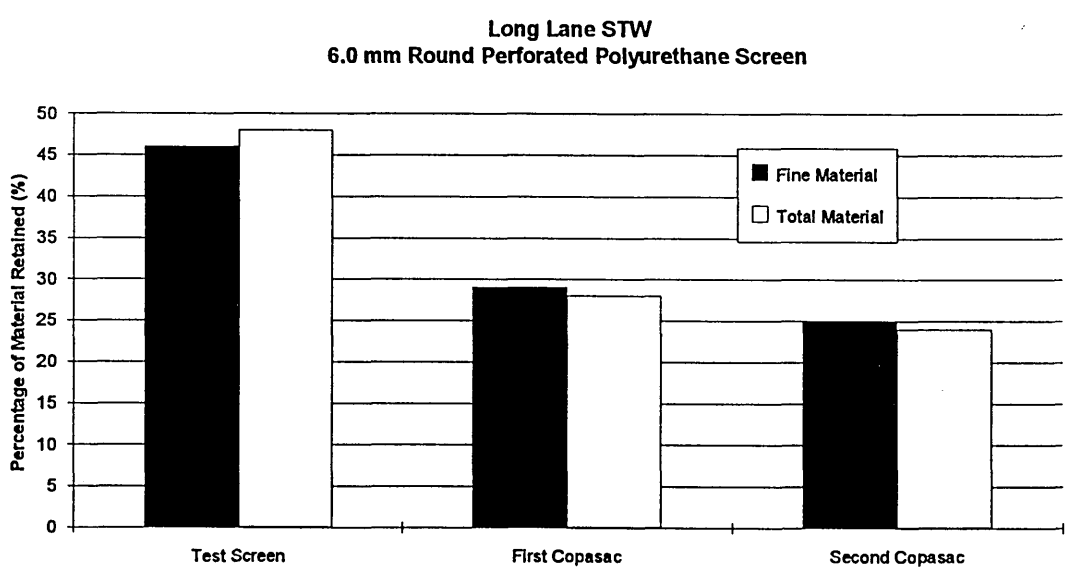


Figure D7

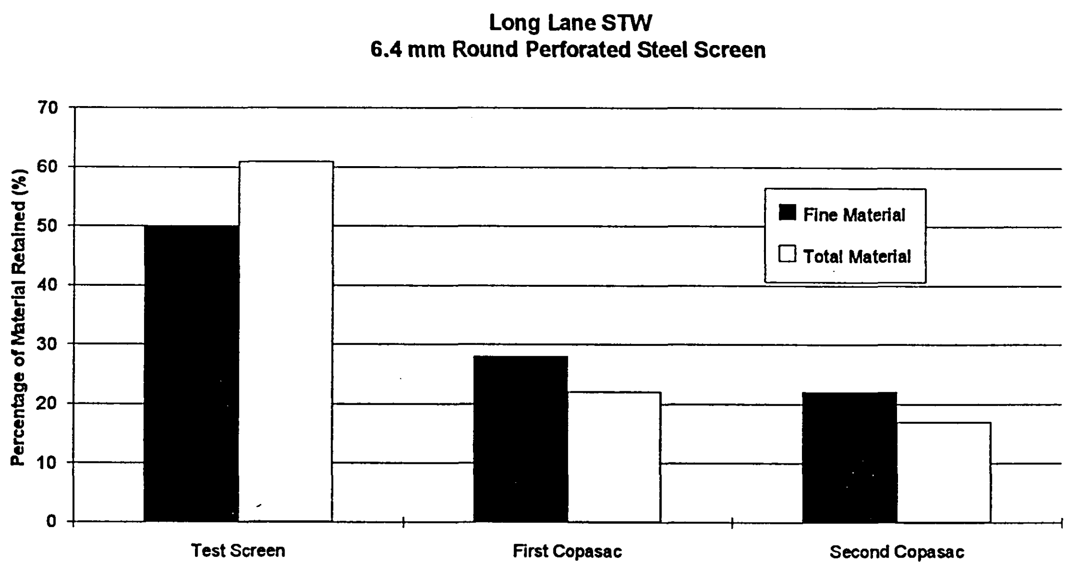


Figure D8

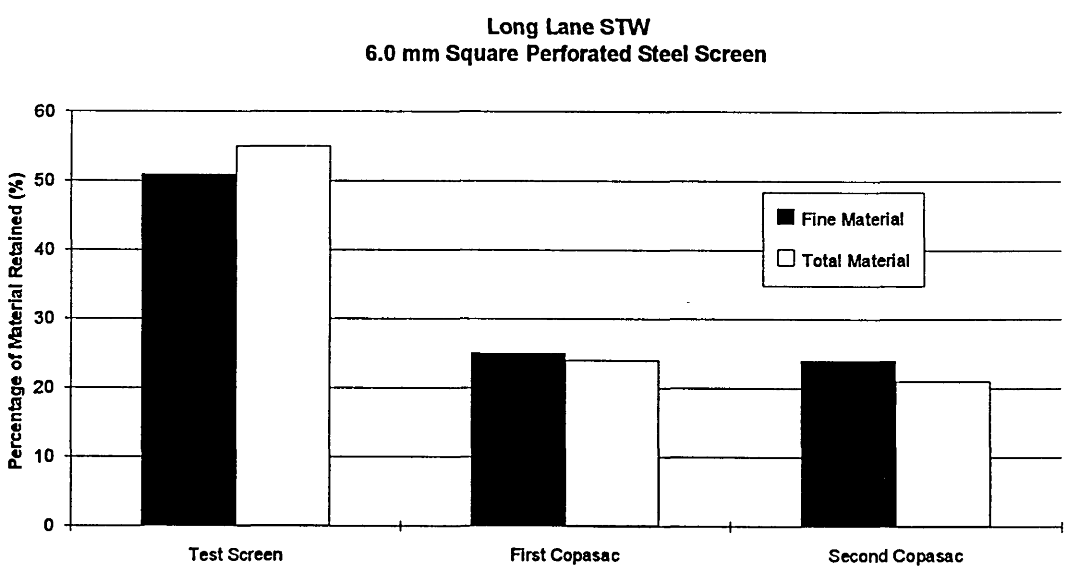
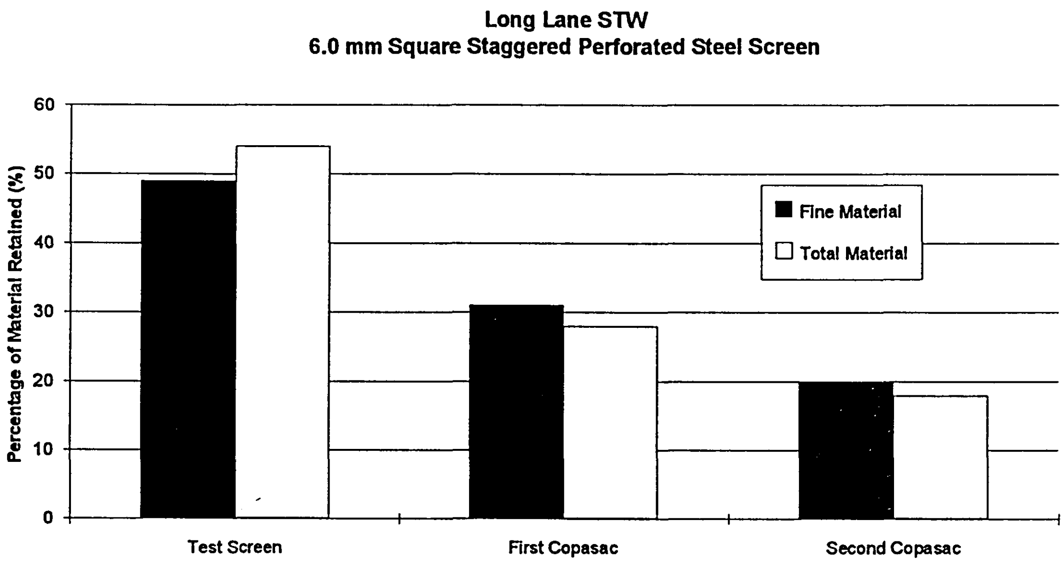


Figure D9



Long Lane STW
6.0 mm Square Staggered Perforated Steel Screen
Percentage of Material Retained (%)
60
50
40
30
20
10
0
Fine Material
Total Material
Test Screen
First Copasac
Second Copasac

Figure D10

Laboratory Full Scale Model of Holbrook STW

Comparison of Mean Screen Retention Efficiency for three Screen system

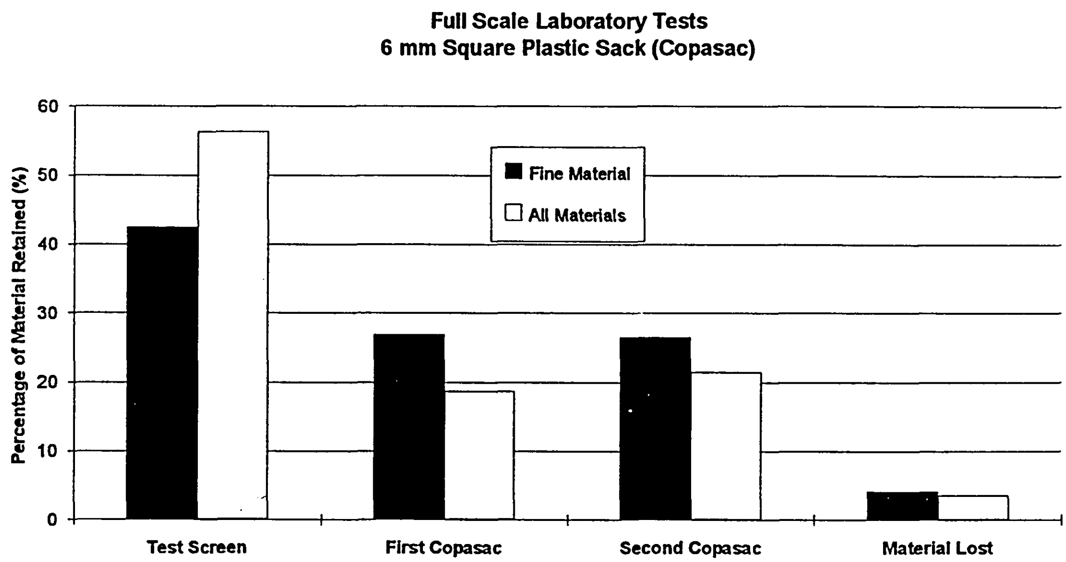


Figure D11

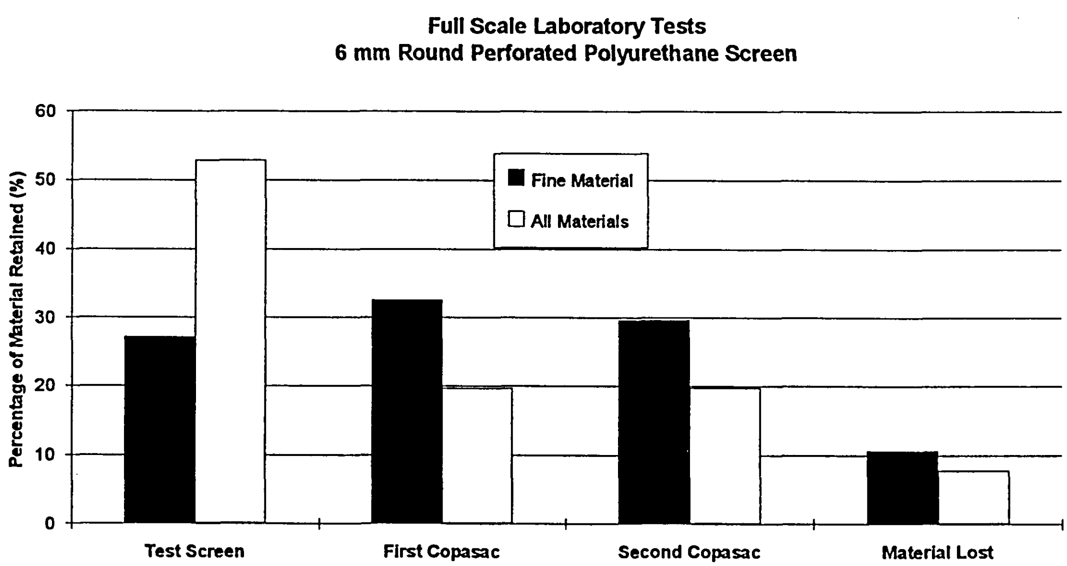


Figure D12

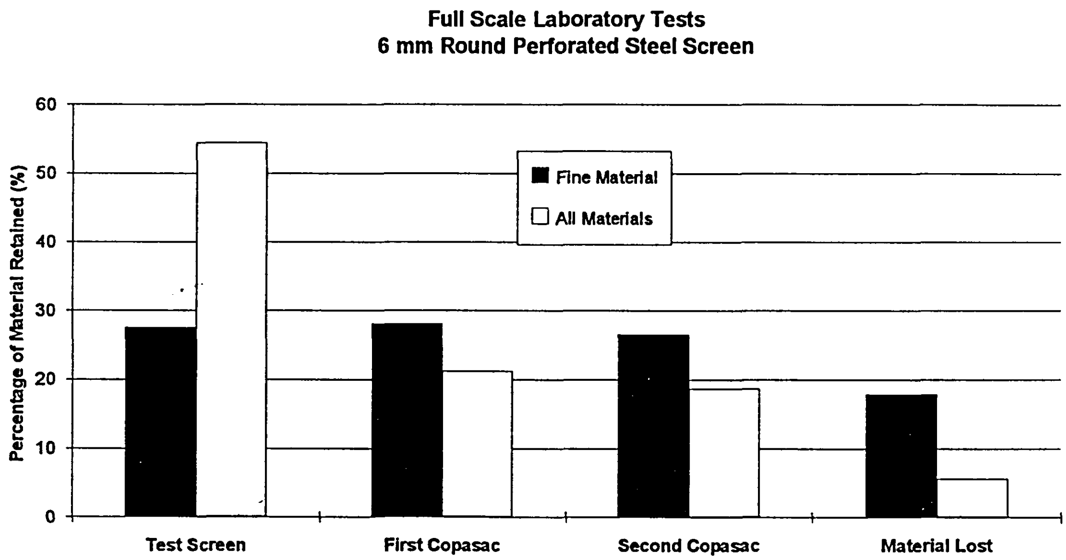


Figure D13

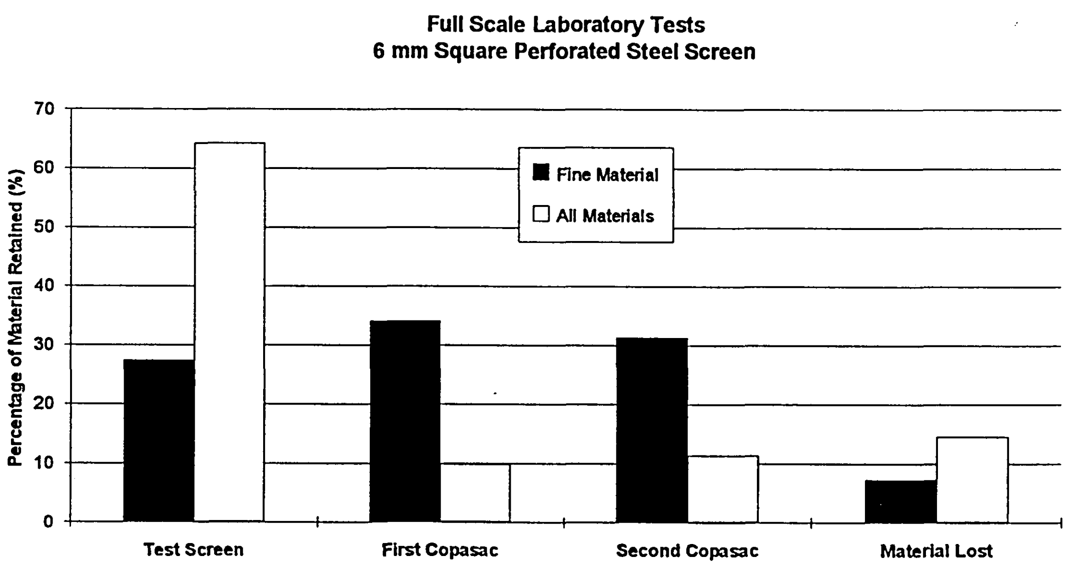


Figure D14

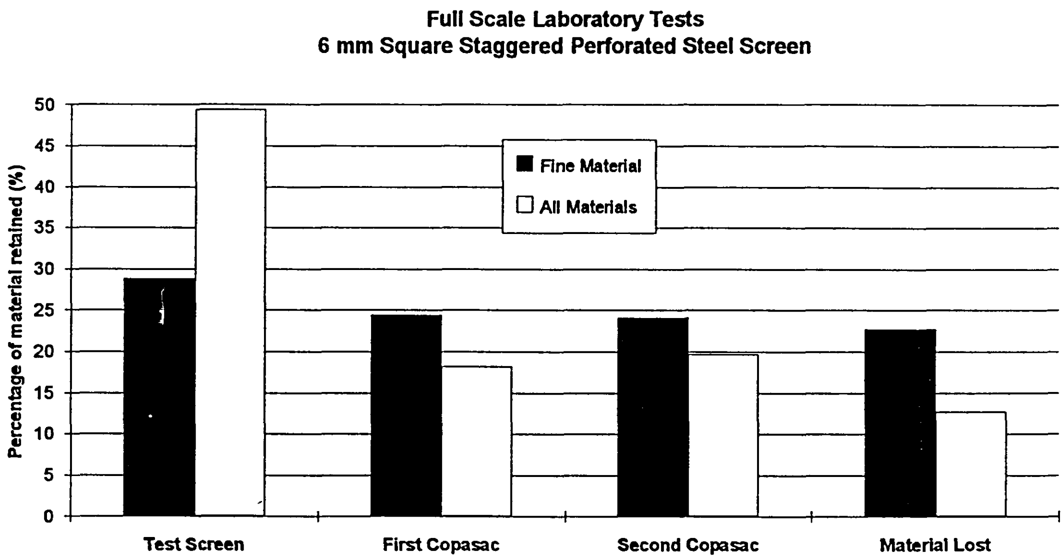

Full Scale Laboratory Tests
6 mm Square Staggered Perforated Steel Screen
Percentage of material retained (%)
50
45
40
35
30
25
20
15
10
5
0
Fine Material
All Materials
Test Screen
First Copasac
Second Copasac
Material Lost

Figure D15

Laboratory Full Scale Model of Holbrook STW

Comparison of Mean Screen Retention Efficiency

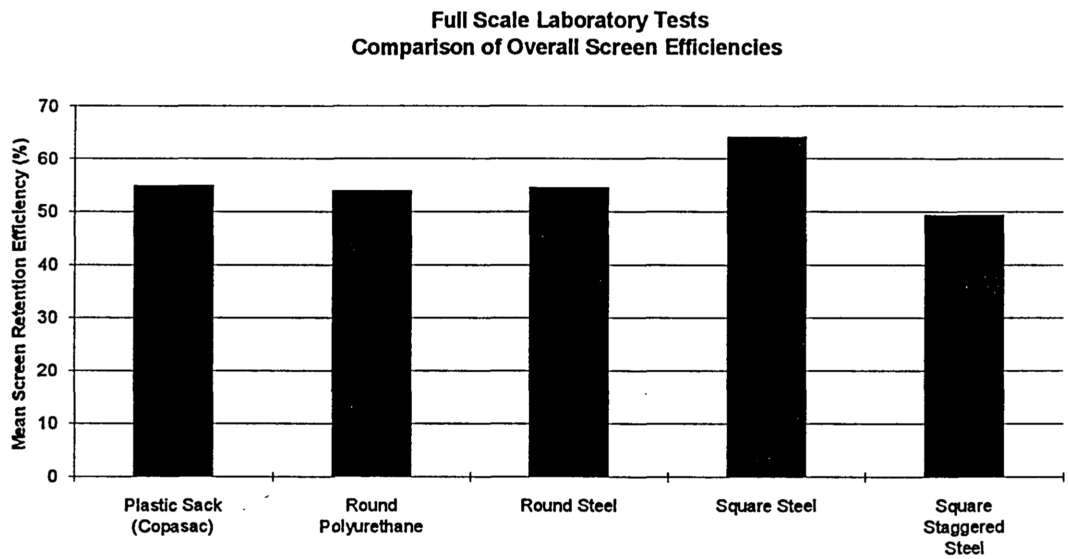


Figure D16

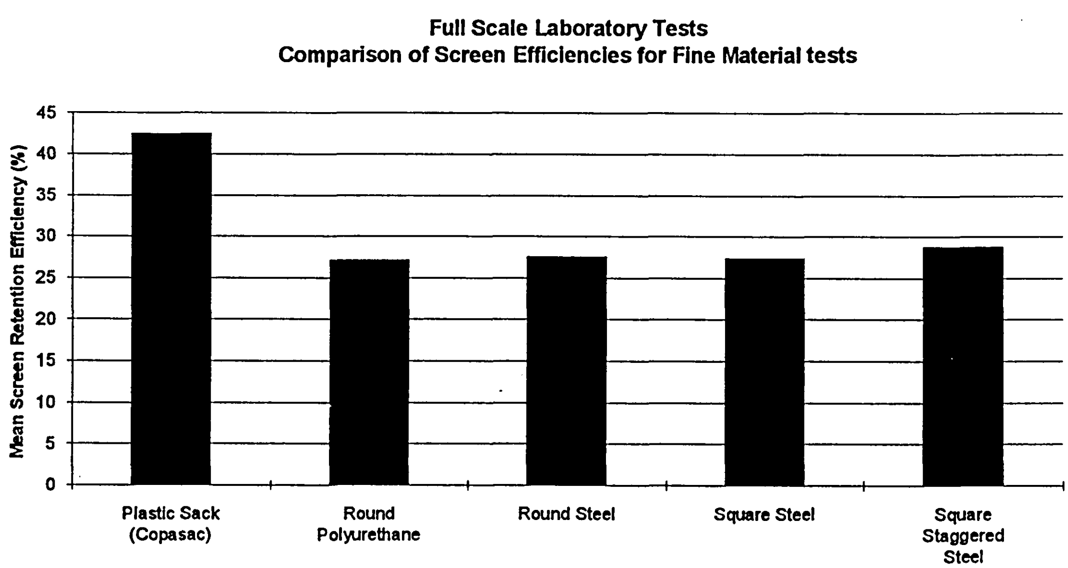


Figure D17

Holbrook and Long Lane STW's

Comparison of Mean Screen Retention Efficiency

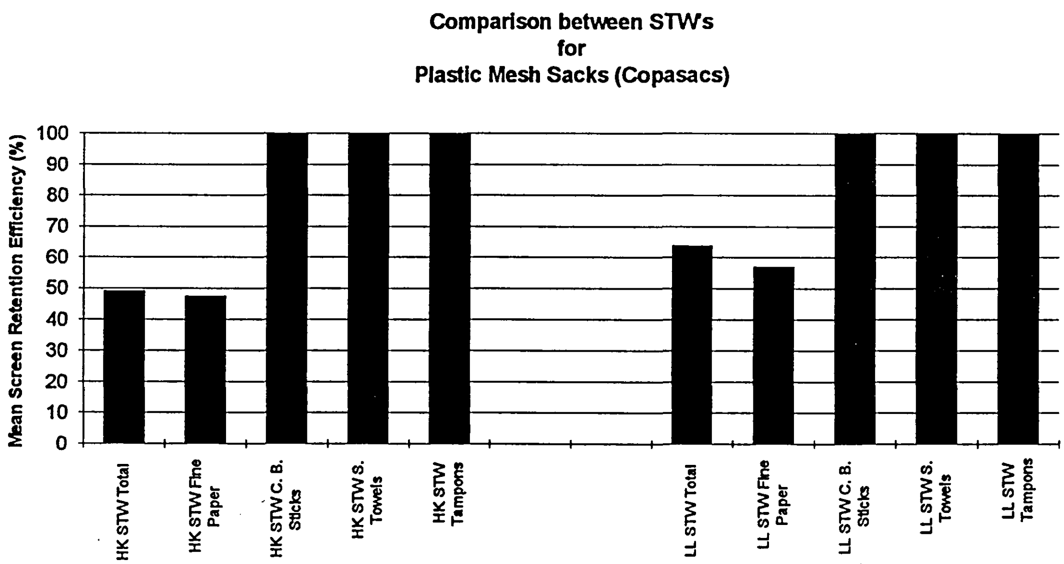


Figure D18

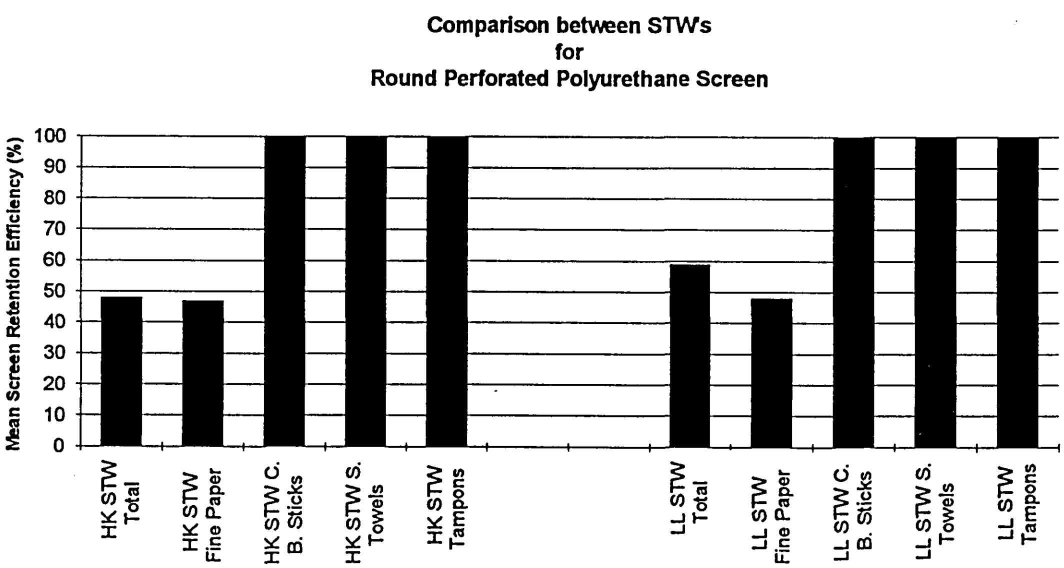


Figure D19

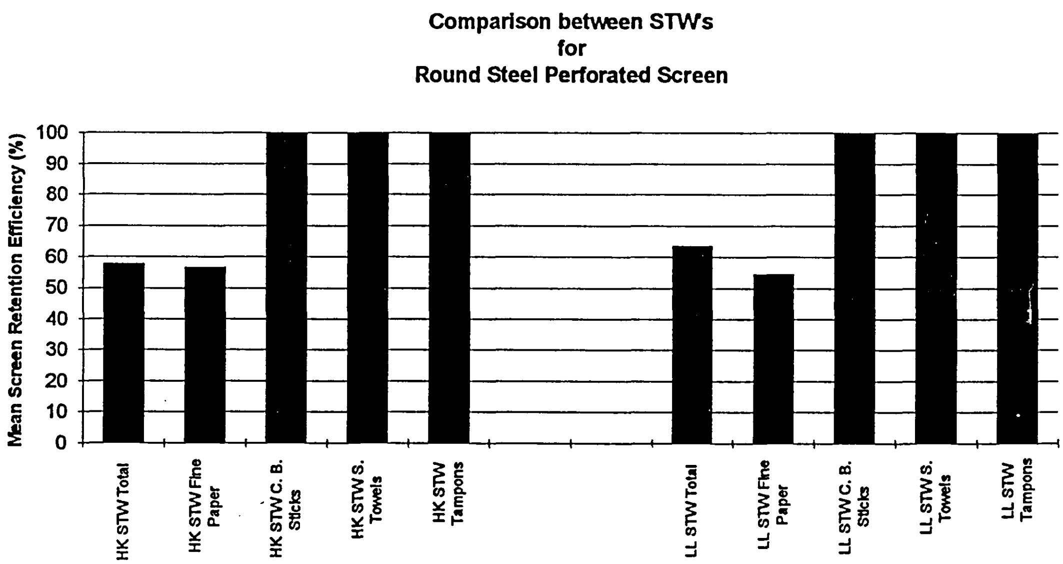


Figure D20

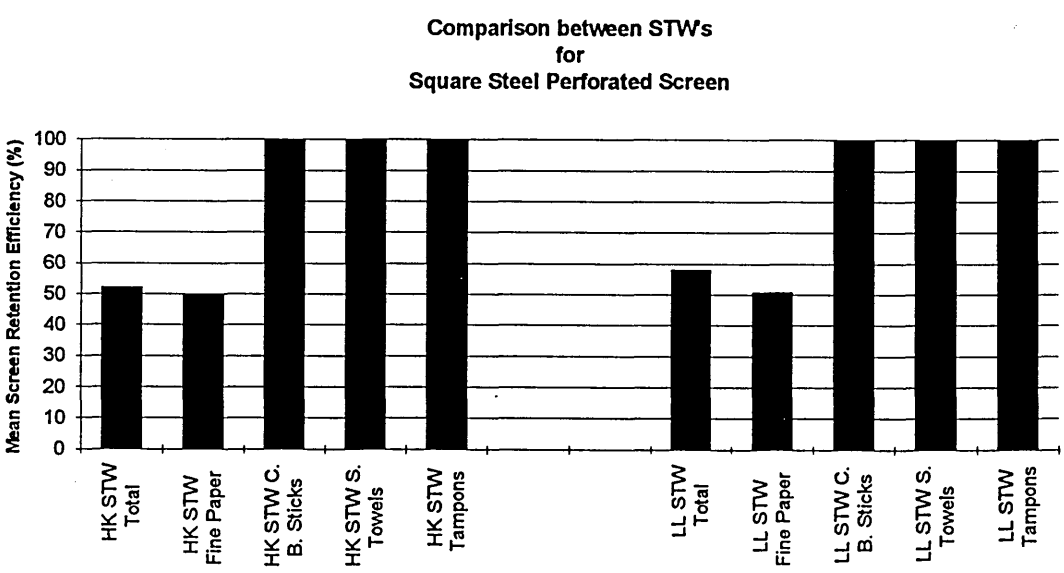
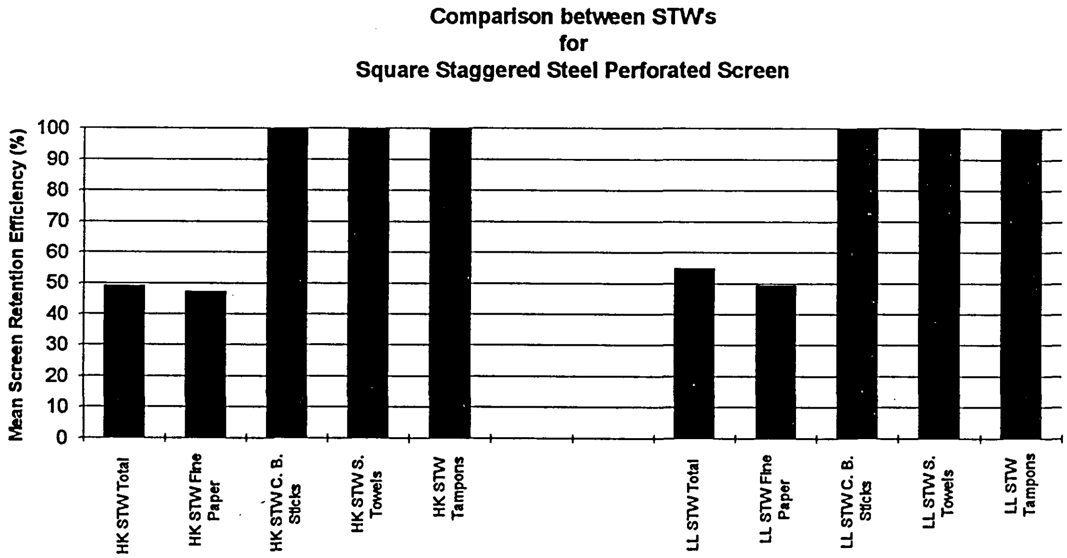


Figure D21



Comparison between STWs
for
Square Staggered Steel Perforated Screen
Mean Screen Retention Efficiency (%)
100
90
80
70
60
50
40
30
20
10
0
HK STW Total
HK STW Fine Paper
HK STW C. B. Sticks
HK STW S. Towels
HK STW Tampons
LL STW Total
LL STW Fine Paper
LL STW C. B. Sticks
LL STW S. Towels
LL STW Tampons

Figure D22

Comparison of Screening Media Efficiencies

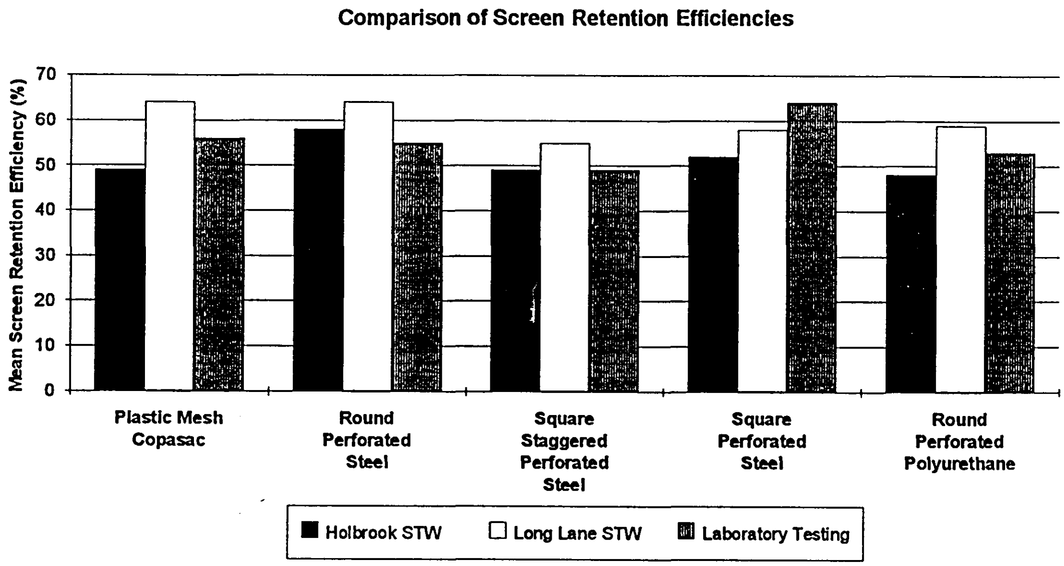


Figure D23

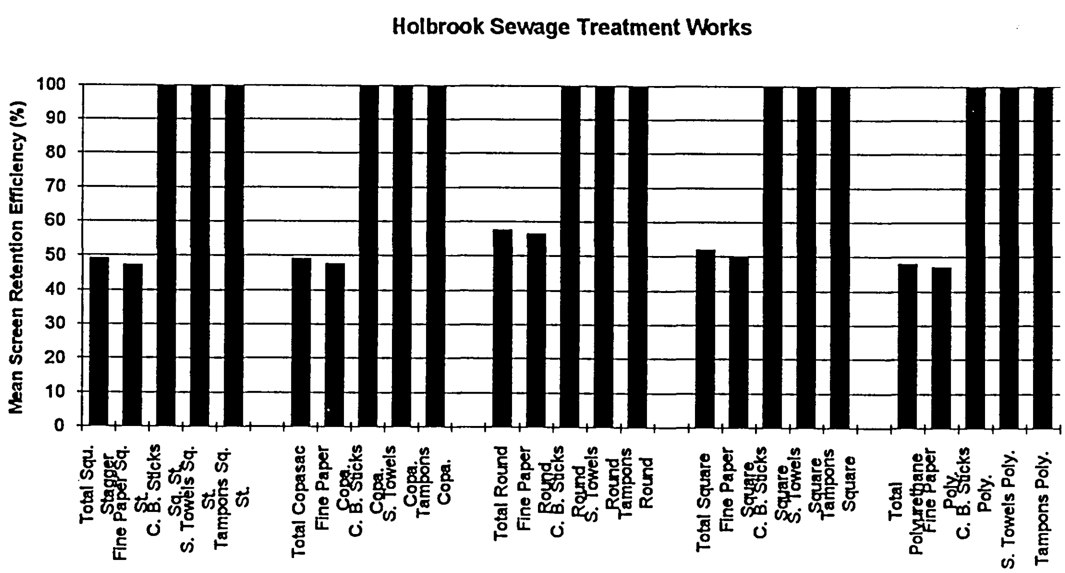


Figure D24

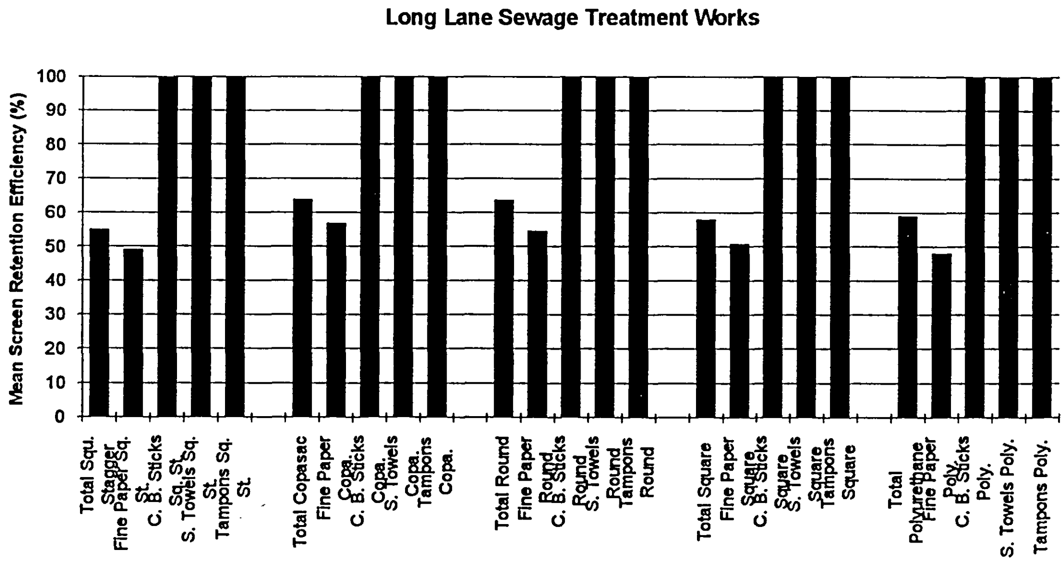


Figure D25

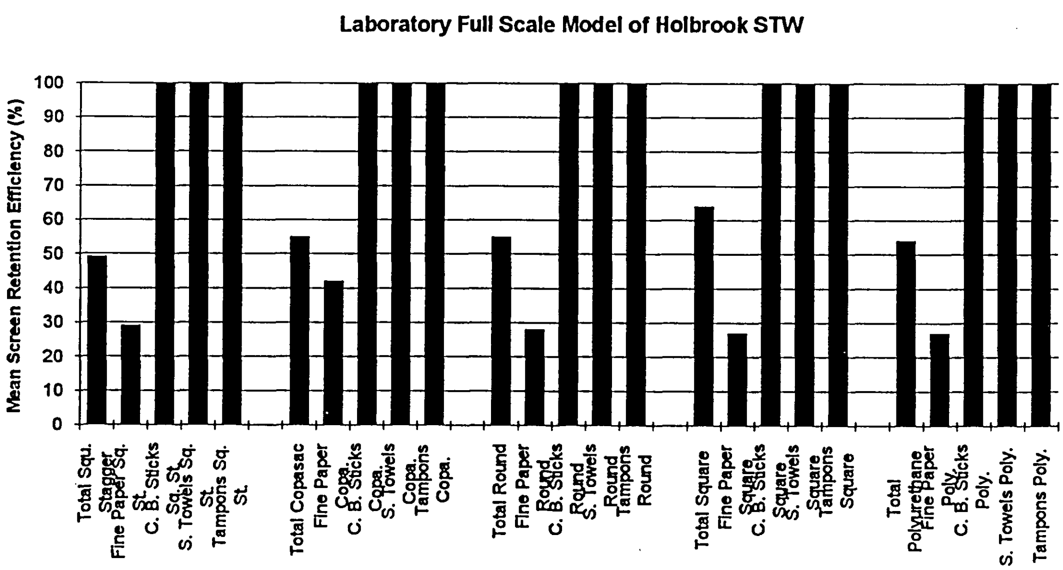


Figure D26

6.0 mm Plastic Mesh (Copasac) Screen

CLEAN - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	37.90	2.639	88	77	0.008
100	22.58	4.429	103	88	0.012
100	17.39	5.750	112	95	0.014
100	14.32	6.983	123	103	0.017
100	12.80	7.813	129	107	0.019
100	11.16	8.961	137	113	0.021
100	9.63	10.384	146	119	0.024
100	8.39	11.919	152	124	0.025
100	8.04	12.438	160	129	0.028
100	6.86	14.577	167	134	0.030
100	6.26	15.974	174	138	0.033
100	5.99	16.694	180	143	0.034
100	5.39	18.553	187	147	0.037
100	5.33	18.762	193	151	0.039
100	4.89	20.450	199	155	0.041
100	4.55	21.978	205	159	0.043
100	4.34	23.041	212	164	0.045
100	4.19	23.866	217	168	0.046
100	3.72	26.882	230	177	0.050

CLEAN - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	35.23	2.838	138	134	0.001
100	23.30	4.292	148	143	0.002
100	19.22	5.203	154	148	0.003
100	14.97	6.680	162	155	0.004
100	12.21	8.190	171	162	0.006
100	10.54	9.488	177	166	0.008
100	9.52	10.504	185	173	0.009
100	8.40	11.905	191	177	0.011
100	7.52	13.298	197	181	0.013
100	7.04	14.205	204	186	0.015
100	6.42	15.576	209	190	0.016
100	6.23	16.051	215	195	0.017
100	5.66	17.668	221	198	0.020
100	5.02	19.920	227	202	0.022
100	4.72	21.186	232	207	0.022
100	4.59	21.786	237	210	0.024
100	4.27	23.419	243	213	0.027
100	3.89	25.707	248	215	0.030
100	3.70	27.027	259	225	0.031

6.0 mm Plastic Mesh (Copasac) Screen

CLEAN - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	31.80	3.145	203	200	0.000
100	24.32	4.112	211	208	0.000
100	18.77	5.328	218	215	0.000
100	14.52	6.887	225	221	0.001
100	12.33	8.110	232	226	0.003
100	10.58	9.452	239	233	0.003
100	9.96	10.040	245	238	0.004
100	8.23	12.151	250	243	0.004
100	7.65	13.072	257	248	0.006
100	7.08	14.124	262	252	0.007
100	6.36	15.723	267	256	0.008
100	6.00	16.667	272	260	0.009
100	5.64	17.730	278	266	0.009
100	5.16	19.380	283	270	0.010
100	5.02	19.920	288	273	0.012
100	4.48	22.321	293	278	0.012
100	4.46	22.422	298	280	0.015
100	4.21	23.753	304	285	0.016
100	3.45	28.986	320	299	0.018

CLEAN - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.88	2.867	253	250	0.000
100	23.70	4.219	260	257	0.000
100	18.43	5.426	268	265	0.000
100	14.79	6.761	275	271	0.001
100	12.49	8.006	282	278	0.001
100	10.23	9.775	288	283	0.002
100	9.50	10.526	293	288	0.002
100	8.47	11.806	299	293	0.003
100	7.59	13.175	304	298	0.003
100	6.82	14.663	310	303	0.004
100	6.17	16.207	315	308	0.004
100	5.86	17.065	320	312	0.005
100	5.51	18.149	325	316	0.006
100	5.43	18.416	330	320	0.007
100	4.99	20.040	335	325	0.007

6.0 mm Round Perforated Polyurethane Screen

CLEAN - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	36.62	2.731	89	78	0.008
100	21.38	4.677	104	90	0.011
100	18.78	5.325	111	96	0.012
100	14.41	6.940	120	102	0.015
100	12.81	7.806	128	108	0.017
100	10.41	9.606	136	114	0.019
100	9.27	10.787	143	120	0.020
100	8.29	12.063	150	125	0.022
100	7.35	13.605	157	130	0.024
100	7.21	13.870	164	135	0.026
100	6.41	15.601	170	140	0.027
100	5.78	17.301	176	145	0.028
100	5.64	17.730	182	146	0.033
100	5.51	18.149	188	150	0.035
100	4.78	20.921	195	156	0.036
100	4.45	22.472	200	160	0.037
100	4.34	23.041	207	166	0.038
100	4.05	24.691	211	171	0.037
100	3.66	27.322	223	180	0.040

CLEAN - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	33.76	2.962	139	135	0.001
100	23.27	4.297	147	142	0.002
100	18.23	5.485	155	149	0.003
100	15.45	6.472	162	155	0.004
100	12.51	7.994	170	162	0.005
100	10.39	9.625	177	168	0.006
100	9.68	10.331	184	173	0.008
100	8.13	12.300	190	178	0.009
100	7.45	13.423	195	182	0.010
100	7.10	14.085	201	187	0.011
100	6.44	15.528	207	191	0.013
100	5.99	16.694	211	195	0.013
100	5.55	18.018	217	198	0.016
100	5.28	18.939	222	203	0.016
100	4.85	20.619	227	206	0.018
100	4.34	23.041	232	209	0.020
100	4.21	23.753	236	213	0.020
100	4.19	23.866	241	215	0.023
100	3.73	26.810	249	222	0.024

6.0 mm Round Perforated Polyurethane Screen

CLEAN - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.97	2.860	202	199	0.000
100	23.43	4.268	210	206	0.001
100	18.69	5.350	218	214	0.001
100	14.66	6.821	225	220	0.002
100	12.38	8.078	230	225	0.002
100	10.82	9.242	237	231	0.003
100	9.43	10.604	242	236	0.003
100	8.81	11.351	248	241	0.004
100	7.96	12.563	254	246	0.005
100	6.95	14.388	259	250	0.006
100	6.50	15.385	264	255	0.006
100	6.09	16.420	269	260	0.006
100	5.70	17.544	274	263	0.008
100	5.05	19.802	279	267	0.009
100	4.68	21.368	283	271	0.009
100	4.44	22.523	288	275	0.010
100	4.32	23.148	293	279	0.011
100	4.20	23.810	297	283	0.011
100	3.64	27.473	308	293	0.012

CLEAN - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.35	2.911	246	243	0.000
100	21.34	4.686	255	252	0.000
100	18.66	5.359	261	258	0.000
100	14.76	6.775	268	264	0.001
100	12.33	8.110	275	270	0.002
100	11.16	8.961	282	277	0.002
100	9.51	10.515	287	281	0.003
100	8.57	11.669	292	285	0.004
100	7.88	12.690	298	290	0.005
100	7.02	14.245	302	294	0.005
100	5.95	16.807	309	300	0.006
100	5.91	16.920	313	302	0.008
100	5.61	17.825	317	306	0.008
100	5.22	19.157	322	310	0.009
100	4.93	20.284	326	313	0.010

6.4 mm Round Perforated Steel Screen

CLEAN - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	39.06	2.560	93	78	0.012
100	22.71	4.403	110	89	0.018
100	17.69	5.653	120	95	0.022
100	14.83	6.743	130	100	0.027
100	12.42	8.052	142	108	0.031
100	10.99	9.099	152	114	0.035
100	9.43	10.604	161	118	0.040
100	8.63	11.587	170	125	0.042
100	7.49	13.351	179	129	0.047
100	6.86	14.577	188	132	0.053
100	6.34	15.773	195	135	0.057
100	5.91	16.920	203	142	0.058
100	5.68	17.606	211	149	0.059
100	5.38	18.587	219	155	0.061
100	4.84	20.661	227	155	0.069
100	4.40	22.727	234	158	0.073
100	4.30	23.256	242	159	0.080
100	4.08	24.510	247	156	0.088
100	3.72	26.882	259	156	0.100

CLEAN - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.54	2.895	142	137	0.002
100	24.55	4.073	152	144	0.005
100	18.16	5.507	161	151	0.007
100	15.52	6.443	168	156	0.009
100	12.82	7.800	177	162	0.012
100	10.98	9.107	188	169	0.016
100	9.70	10.309	195	173	0.019
100	8.27	12.092	202	178	0.021
100	7.55	13.245	210	183	0.024
100	7.15	13.986	218	188	0.027
100	6.26	15.974	226	192	0.031
100	6.24	16.026	234	199	0.032
100	5.58	17.921	239	200	0.036
100	5.39	18.553	248	204	0.041
100	4.79	20.877	255	211	0.041
100	4.52	22.124	260	210	0.047
100	4.19	23.866	266	210	0.053
100	4.06	24.631	273	211	0.059
100	4.04	24.752	280	212	0.065

6.4 mm Round Perforated Steel Screen

CLEAN - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.43	2.904	203	200	0.000
100	24.22	4.129	212	208	0.001
100	18.25	5.479	221	215	0.003
100	14.67	6.817	230	223	0.004
100	12.50	8.000	236	228	0.005
100	11.06	9.042	243	233	0.007
100	9.43	10.604	250	238	0.009
100	8.20	12.195	256	243	0.010
100	7.70	12.987	263	248	0.012
100	6.99	14.306	270	253	0.014
100	6.28	15.924	277	258	0.016
100	5.94	16.835	283	262	0.018
100	5.55	18.018	289	266	0.020
100	5.34	18.727	295	270	0.022
100	4.77	20.964	301	273	0.025
100	4.44	22.523	307	278	0.026
100	4.27	23.419	313	281	0.029
100	3.99	25.063	319	285	0.031
100	3.83	26.110	326	290	0.033

CLEAN - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	31.84	3.141	246	243	0.000
100	23.00	4.348	255	252	0.000
100	18.49	5.408	261	258	0.000
100	14.76	6.775	268	264	0.001
100	12.03	8.313	275	270	0.002
100	10.78	9.276	282	277	0.002
100	9.40	10.638	287	281	0.003
100	8.79	11.377	292	285	0.004
100	7.09	14.104	298	290	0.005
100	6.83	14.641	302	294	0.005
100	6.66	15.015	309	300	0.006
100	6.09	16.420	313	302	0.008
100	5.64	17.730	317	306	0.008

6.0 mm Square Perforated Steel Screen

CLEAN - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	33.11	3.020	90	81	0.006
100	23.47	4.261	99	89	0.007
100	18.19	5.498	108	95	0.010
100	15.44	6.477	115	100	0.012
100	12.43	8.045	123	107	0.013
100	10.82	9.242	132	113	0.016
100	9.55	10.471	139	119	0.017
100	8.24	12.136	145	124	0.018
100	8.06	12.407	152	128	0.021
100	7.25	13.793	159	133	0.023
100	6.48	15.432	165	138	0.024
100	6.17	16.207	172	142	0.027
100	5.47	18.282	180	147	0.030
100	5.19	19.268	183	149	0.031
100	4.79	20.877	189	153	0.033
100	4.50	22.222	195	159	0.033
100	4.23	23.641	200	165	0.032
100	4.20	23.810	206	171	0.032
100	3.93	25.445	213	176	0.034

CLEAN - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	35.23	2.838	141	138	0.000
100	24.39	4.100	150	145	0.002
100	18.35	5.450	157	152	0.002
100	14.58	6.859	165	159	0.003
100	11.92	8.389	172	165	0.004
100	10.59	9.443	177	170	0.004
100	9.50	10.526	184	175	0.006
100	8.81	11.351	190	180	0.007
100	7.18	13.928	195	185	0.007
100	7.03	14.225	201	189	0.009
100	6.37	15.699	207	193	0.011
100	5.90	16.949	211	197	0.011
100	5.61	17.825	216	201	0.012
100	5.42	18.450	222	206	0.013
100	4.81	20.790	227	209	0.015
100	4.59	21.786	231	211	0.017
100	4.45	22.472	236	213	0.020
100	4.11	24.331	242	221	0.018
100	3.81	26.247	249	223	0.023

6.0 mm Square Perforated Steel Screen

CLEAN - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	35.02	2.856	205	202	0.000
100	24.36	4.105	211	208	0.000
100	18.24	5.482	219	216	0.000
100	14.82	6.748	226	222	0.001
100	12.20	8.197	232	228	0.001
100	10.91	9.166	238	233	0.002
100	9.21	10.858	244	239	0.002
100	8.82	11.338	249	244	0.002
100	7.74	12.920	255	248	0.004
100	6.78	14.749	260	253	0.004
100	5.95	16.807	265	258	0.004
100	5.88	17.007	270	262	0.005
100	5.69	17.575	275	266	0.006
100	5.10	19.608	280	271	0.006
100	4.90	20.408	285	274	0.008
100	4.43	22.573	289	278	0.008
100	4.39	22.779	295	283	0.009
100	4.06	24.631	298	285	0.010
100	3.61	27.701	305	291	0.011

CLEAN - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	35.13	2.847	252	249	0.000
100	23.94	4.177	261	258	0.000
100	18.19	5.498	267	264	0.000
100	15.09	6.627	274	270	0.001
100	12.27	8.150	279	275	0.001
100	10.54	9.488	286	282	0.001
100	9.26	10.799	292	288	0.001
100	8.21	12.180	297	293	0.001
100	7.55	13.245	302	297	0.002
100	6.99	14.306	307	302	0.002
100	6.48	15.432	312	306	0.003
100	5.94	16.835	317	311	0.003
100	5.52	18.116	322	315	0.004
100	5.02	19.920	326	319	0.004
100	4.80	20.833	330	323	0.004

6.0 mm Square Staggered Steel Screen

CLEAN - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	32.78	3.051	95	82	0.010
100	23.28	4.296	106	90	0.013
100	17.34	5.767	115	96	0.016
100	14.91	6.707	124	102	0.019
100	12.05	8.299	134	109	0.022
100	10.62	9.416	141	113	0.025
100	9.33	10.718	150	120	0.027
100	8.50	11.765	158	124	0.031
100	7.50	13.333	166	130	0.033
100	6.79	14.728	173	134	0.036
100	6.45	15.504	180	139	0.038
100	5.91	16.920	187	142	0.042
100	5.56	17.986	194	146	0.045
100	4.83	20.704	201	152	0.046
100	4.70	21.277	207	157	0.047
100	4.23	23.641	213	162	0.048
100	4.21	23.753	220	168	0.049
100	4.16	24.038	227	171	0.053
100	3.17	31.546	234	174	0.057

CLEAN - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	35.52	2.815	140	135	0.002
100	24.75	4.040	148	142	0.003
100	18.78	5.325	156	149	0.004
100	15.77	6.341	163	153	0.007
100	12.83	7.794	170	159	0.008
100	10.34	9.671	178	164	0.011
100	9.22	10.846	186	170	0.013
100	8.27	12.092	190	174	0.013
100	8.08	12.376	197	178	0.016
100	6.98	14.327	204	182	0.019
100	6.61	15.129	210	186	0.021
100	5.86	17.065	216	191	0.022
100	5.37	18.622	222	195	0.024
100	5.18	19.305	228	198	0.027
100	4.93	20.284	232	200	0.029
100	4.67	21.413	239	205	0.031
100	4.43	22.573	243	208	0.032
100	4.07	24.570	248	210	0.035
100	3.71	26.954	256	215	0.038

6.0 mm Square Staggered Steel Screen

CLEAN - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	40.44	2.473	195	192	0.000
100	23.63	4.232	207	203	0.001
100	19.13	5.227	214	209	0.002
100	15.33	6.523	220	215	0.002
100	12.61	7.930	228	222	0.003
100	10.82	9.242	234	227	0.004
100	9.36	10.684	240	232	0.005
100	8.57	11.669	246	237	0.006
100	7.72	12.953	251	241	0.007
100	6.86	14.577	256	244	0.009
100	6.56	15.244	260	247	0.010
100	6.11	16.367	265	251	0.011
100	5.75	17.391	271	255	0.013
100	5.04	19.841	276	259	0.014
100	5.01	19.960	280	261	0.016
100	4.63	21.598	286	266	0.017
100	4.26	23.474	290	268	0.019
100	4.01	24.938	295	272	0.020
100	3.75	26.667	301	275	0.023

Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	37.51	2.666	246	243	0.000
100	24.15	4.141	255	252	0.000
100	18.95	5.277	261	258	0.000
100	15.06	6.640	268	264	0.001
100	12.64	7.911	275	270	0.002
100	10.90	9.174	282	277	0.002
100	9.77	10.235	287	281	0.003
100	8.36	11.962	292	285	0.004
100	7.79	12.837	298	290	0.005
100	7.33	13.643	302	294	0.005
100	6.60	15.152	309	300	0.006
100	5.85	17.094	313	302	0.008
100	5.58	17.921	317	306	0.008
100	5.21	19.194	322	310	0.009
100	4.78	20.921	326	313	0.010
100	4.46	22.422	332	317	0.012

6.0 mm Plastic Mesh (Copasac) Screen

PARTIALLY BLINDED - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	31.47	3.178	103	65	0.030
100	24.75	4.040	115	72	0.035
100	18.10	5.525	127	78	0.041
100	16.06	6.227	137	84	0.045
100	12.22	8.183	150	85	0.057
100	10.81	9.251	160	87	0.065
100	9.62	10.395	170	61	0.101
100	8.34	11.990	180	64	0.108
100	7.65	13.072	189	66	0.115
100	7.44	13.441	197	69	0.120
100	6.56	15.244	204	71	0.125
100	6.00	16.667	211	74	0.129
100	5.72	17.483	220	77	0.135
100	5.34	18.727	229	79	0.142
100	5.00	20.000	236	82	0.146
100	4.66	21.459	244	84	0.152
100	4.29	23.310	251	86	0.157
100	4.03	24.814	258	87	0.163
100	3.69	27.100	267	90	0.169

PARTIALLY BLINDED - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	33.93	2.947	132	120	0.004
100	23.69	4.221	143	126	0.009
100	19.03	5.255	152	132	0.012
100	15.28	6.545	163	138	0.017
100	12.59	7.943	174	145	0.021
100	11.21	8.921	184	150	0.026
100	9.78	10.225	192	155	0.029
100	8.66	11.547	200	160	0.032
100	7.72	12.953	208	163	0.037
100	7.18	13.928	217	168	0.041
100	6.47	15.456	225	173	0.044
100	5.72	17.483	233	176	0.049
100	5.40	18.519	241	180	0.053
100	5.03	19.881	249	185	0.056
100	4.91	20.367	257	188	0.061
100	4.66	21.459	263	192	0.063
100	4.06	24.631	271	193	0.070
100	4.03	24.814	278	196	0.074
100	3.72	26.882	287	203	0.076

6.0 mm Plastic Mesh (Copasac) Screen

PARTIALLY BLINDED - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	31.62	3.163	190	182	0.000
100	22.53	4.439	202	191	0.003
100	17.59	5.685	212	198	0.006
100	14.38	6.954	220	204	0.008
100	12.69	7.880	227	209	0.010
100	10.50	9.524	236	215	0.013
100	9.16	10.917	244	221	0.015
100	8.63	11.587	251	225	0.018
100	7.81	12.804	258	229	0.021
100	7.06	14.164	265	233	0.024
100	6.72	14.881	272	238	0.026
100	6.12	16.340	279	242	0.029
100	5.63	17.762	287	247	0.032
100	5.28	18.939	295	250	0.037
100	4.81	20.790	302	255	0.039
100	4.53	22.075	307	257	0.042
100	4.16	24.038	315	262	0.045
100	4.03	24.814	322	265	0.049
100	3.75	26.667	329	270	0.051

PARTIALLY BLINDED - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	35	32	0.000
100	34.07	2.935	239	231	0.000
100	22.59	4.427	250	241	0.001
100	17.63	5.672	260	248	0.004
100	14.63	6.835	266	253	0.005
100	11.47	8.718	276	261	0.007
100	10.87	9.200	283	266	0.009
100	10.06	9.940	290	271	0.011
100	8.78	11.390	296	275	0.013
100	7.84	12.755	303	281	0.014
100	7.31	13.680	310	285	0.017
100	6.28	15.924	318	291	0.019
100	5.93	16.863	324	295	0.021
100	5.91	16.920	330	299	0.023
100	5.25	19.048	337	303	0.026
100	4.81	20.790	342	307	0.027

6.0 mm Round Perforated Polyurethane Screen

PARTIALLY BLINDED - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	38.21	2.617	114	59	0.049
100	23.85	4.193	134	75	0.053
100	19.10	5.236	149	80	0.063
100	15.45	6.472	161	84	0.071
100	12.89	7.758	176	91	0.079
100	10.79	9.268	186	85	0.095
100	9.76	10.246	199	67	0.126
100	8.63	11.587	207	70	0.131
100	7.59	13.175	220	72	0.142
100	6.78	14.749	230	75	0.149
100	6.56	15.244	240	77	0.157
100	5.90	16.949	252	77	0.169
100	5.37	18.622	262	79	0.177
100	5.07	19.724	270	81	0.183
100	4.78	20.921	282	86	0.190
100	4.50	22.222	290	90	0.194
100	4.37	22.883	299	93	0.200
100	4.18	23.923	307	94	0.207
100	3.29	30.395	338	94	0.238

PARTIALLY BLINDED - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	33.68	2.969	142	125	0.011
100	21.69	4.610	152	130	0.016
100	18.55	5.391	168	138	0.024
100	15.40	6.494	176	142	0.028
100	11.24	8.897	189	148	0.035
100	10.77	9.285	200	153	0.041
100	9.79	10.215	209	157	0.046
100	8.52	11.737	218	162	0.050
100	7.70	12.987	230	166	0.058
100	7.15	13.986	239	170	0.063
100	6.45	15.504	249	175	0.068
100	6.05	16.529	259	178	0.075
100	5.76	17.361	267	182	0.079
100	5.35	18.692	277	187	0.084
100	4.48	22.321	287	191	0.090
100	4.36	22.936	297	194	0.097
100	4.29	23.310	305	197	0.102
100	4.13	24.213	314	202	0.106
100	3.82	26.178	333	209	0.118

6.0 mm Round Perforated Polyurethane Screen

PARTIALLY BLINDED - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	34.59	2.891	198	187	0.005
100	24.25	4.124	207	194	0.007
100	18.63	5.368	217	200	0.011
100	15.53	6.439	227	205	0.016
100	12.22	8.183	238	211	0.021
100	10.68	9.363	247	216	0.025
100	9.37	10.672	258	222	0.030
100	8.63	11.587	267	227	0.034
100	7.69	13.004	277	231	0.040
100	6.84	14.620	286	236	0.044
100	6.69	14.948	296	240	0.050
100	6.25	16.000	303	244	0.053
100	5.57	17.953	313	248	0.059
100	5.16	19.380	320	252	0.062
100	4.66	21.459	331	257	0.068
100	4.53	22.075	340	266	0.068

PARTIALLY BLINDED - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	34.03	2.939	245	237	0.002
100	23.97	4.172	256	244	0.006
100	18.91	5.288	264	249	0.009
100	15.00	6.667	273	255	0.012
100	12.96	7.716	283	261	0.016
100	11.03	9.066	293	267	0.020
100	9.53	10.493	301	271	0.024
100	8.62	11.601	309	276	0.027
100	7.91	12.642	318	281	0.031
100	7.13	14.025	327	285	0.036
100	6.66	15.015	337	290	0.041

6.4 mm Round Perforated Steel Screen

PARTIALLY BLINDED - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	ownstrea Depth (mm)	Head Loss (m)
0	0.00	0.000	40	32	0.000
100	33.66	2.971	102	64	0.030
100	24.44	4.092	116	50	0.058
100	18.30	5.464	130	54	0.068
100	15.13	6.609	141	55	0.078
100	12.49	8.006	152	56	0.088
100	11.10	9.009	164	59	0.097
100	9.25	10.811	176	63	0.105
100	8.52	11.737	185	66	0.111
100	7.99	12.516	192	67	0.117
100	7.12	14.045	204	71	0.125
100	6.69	14.948	211	73	0.130
100	5.95	16.807	221	76	0.137
100	5.60	17.857	229	80	0.141
100	5.34	18.727	239	81	0.150
100	5.19	19.268	245	85	0.152
100	4.48	22.321	253	88	0.157
100	4.34	23.041	262	90	0.164
100	4.04	24.752	267	92	0.167
100	3.93	25.445	280	97	0.175

PARTIALLY BLINDED - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	ownstrea Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	34.15	2.928	132	120	0.004
100	23.03	4.342	143	127	0.008
100	18.42	5.429	153	133	0.012
100	15.16	6.596	162	139	0.015
100	12.71	7.868	173	145	0.020
100	10.55	9.479	183	151	0.024
100	9.24	10.823	193	156	0.029
100	8.36	11.962	200	161	0.031
100	7.75	12.903	210	165	0.037
100	7.03	14.225	218	170	0.040
100	6.69	14.948	226	174	0.044
100	5.94	16.835	234	178	0.048
100	5.71	17.513	242	183	0.051
100	5.44	18.382	250	185	0.057
100	5.02	19.920	256	189	0.059
100	4.75	21.053	267	192	0.067
100	4.13	24.213	273	196	0.069
100	4.04	24.752	280	201	0.071
100	3.72	26.882	294	209	0.077

6.4 mm Round Perforated Steel Screen

PARTIALLY BLINDED - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	ownstrea Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	32.66	3.062	191	183	0.000
100	23.58	4.241	202	193	0.001
100	19.00	5.263	209	198	0.003
100	15.42	6.485	217	204	0.005
100	12.73	7.855	226	210	0.008
100	10.25	9.756	235	216	0.011
100	9.49	10.537	243	222	0.013
100	8.53	11.723	250	226	0.016
100	7.33	13.643	258	231	0.019
100	6.85	14.599	265	236	0.021
100	6.65	15.038	272	240	0.024
100	6.10	16.393	280	245	0.027
100	5.74	17.422	287	249	0.030
100	5.21	19.194	295	253	0.034
100	4.87	20.534	302	256	0.038
100	4.85	20.619	308	260	0.040
100	4.21	23.753	315	265	0.042
100	4.16	24.038	321	267	0.046
100	3.46	28.902	335	274	0.053

PARTIALLY BLINDED - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	ownstrea Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	33.27	3.006	242	234	0.000
100	23.72	4.216	250	242	0.000
100	18.45	5.420	257	248	0.001
100	15.21	6.575	264	254	0.002
100	12.67	7.893	273	261	0.004
100	10.54	9.488	282	267	0.007
100	9.91	10.091	288	272	0.008
100	8.83	11.325	295	277	0.010
100	7.44	13.441	301	281	0.012
100	7.11	14.065	309	286	0.015
100	6.44	15.528	317	291	0.018
100	6.20	16.129	322	295	0.019
100	5.62	17.794	330	300	0.022
100	5.17	19.342	338	304	0.026
100	4.97	20.121	343	308	0.027

6.0 mm Square Perforated Steel Screen

PARTIALLY BLINDED - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	40	32	0.000
100	34.79	2.874	92	64	0.020
100	23.79	4.203	108	74	0.026
100	18.27	5.473	120	80	0.032
100	14.80	6.757	126	85	0.033
100	12.83	7.794	140	87	0.045
100	10.88	9.191	148	95	0.045
100	9.64	10.373	156	100	0.048
100	8.38	11.933	164	106	0.050
100	7.53	13.280	175	110	0.057
100	6.89	14.514	182	115	0.059
100	6.22	16.077	190	115	0.067
100	6.18	16.181	197	119	0.070
100	5.68	17.606	203	124	0.071
100	5.23	19.120	212	132	0.072
100	4.88	20.492	220	145	0.067
100	4.56	21.930	226	147	0.071
100	4.37	22.883	233	154	0.071
100	4.25	23.529	239	158	0.073
100	3.69	27.100	252	162	0.082

PARTIALLY BLINDED - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	40	32	0.000
100	32.70	3.058	132	121	0.003
100	25.68	3.894	140	126	0.006
100	19.49	5.131	150	132	0.010
100	15.16	6.596	161	140	0.013
100	13.00	7.692	170	145	0.017
100	10.71	9.337	179	151	0.020
100	9.83	10.173	187	157	0.022
100	8.35	11.976	194	160	0.026
100	8.08	12.376	201	165	0.028
100	7.11	14.065	211	171	0.032
100	6.65	15.038	218	175	0.035
100	5.68	17.606	225	180	0.037
100	5.61	17.825	230	182	0.040
100	5.36	18.657	237	185	0.044
100	4.95	20.202	245	191	0.046
100	4.70	21.277	251	194	0.049
100	4.32	23.148	259	196	0.055
100	4.25	23.529	265	198	0.059
100	3.73	26.810	275	205	0.062

6.0 mm Square Perforated Steel Screen

PARTIALLY BLINDED - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	40	32	0.000
100	35.49	2.818	190	182	0.000
100	23.77	4.207	202	192	0.002
100	18.28	5.470	211	199	0.004
100	15.00	6.667	217	204	0.005
100	12.70	7.874	226	211	0.007
100	11.03	9.066	233	216	0.009
100	9.46	10.571	242	223	0.011
100	8.30	12.048	249	227	0.014
100	7.80	12.821	255	232	0.015
100	7.33	13.643	262	236	0.018
100	6.58	15.198	269	240	0.021
100	5.75	17.391	275	245	0.022
100	5.58	17.921	282	248	0.026
100	5.07	19.724	288	253	0.027
100	4.84	20.661	295	256	0.031
100	4.68	21.368	301	260	0.033
100	4.36	22.936	306	263	0.035
100	4.15	24.096	312	267	0.037
100	3.75	26.667	325	275	0.042

PARTIALLY BLINDED - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	40	32	0.000
100	34.36	2.910	242	234	0.000
100	23.35	4.283	251	242	0.001
100	18.29	5.467	258	249	0.001
100	15.49	6.456	267	256	0.003
100	11.86	8.432	275	262	0.005
100	11.04	9.058	281	267	0.006
100	9.79	10.215	289	272	0.009
100	8.96	11.161	295	277	0.010
100	7.92	12.626	301	282	0.011
100	7.12	14.045	307	286	0.013
100	6.52	15.337	315	292	0.015
100	6.02	16.611	322	296	0.018
100	5.59	17.889	328	300	0.020
100	5.19	19.268	333	303	0.022
100	4.82	20.747	340	308	0.024

6.0 mm Square Staggered Steel Screen

PARTIALLY BLINDED - Free Flow

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	34.04	2.938	102	61	0.035
100	22.59	4.427	117	73	0.038
100	18.59	5.379	129	80	0.043
100	14.88	6.720	139	85	0.048
100	12.29	8.137	151	80	0.065
100	10.85	9.217	162	92	0.064
100	9.69	10.320	169	95	0.068
100	8.80	11.364	177	104	0.067
100	7.76	12.887	187	104	0.077
100	6.83	14.641	198	85	0.107
100	6.52	15.337	203	121	0.076
100	5.68	17.606	213	88	0.119
100	5.58	17.921	221	82	0.133
100	5.43	18.416	230	84	0.140
100	5.15	19.417	239	85	0.148
100	4.33	23.095	243	86	0.151
100	4.22	23.697	251	88	0.157
100	3.98	25.126	261	90	0.165
100	3.60	27.778	281	95	0.180

PARTIALLY BLINDED - Submerged (a)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	38.14	2.622	134	122	0.006
100	25.73	3.887	145	128	0.011
100	18.98	5.269	155	135	0.014
100	15.44	6.477	165	141	0.018
100	12.52	7.987	175	146	0.023
100	10.55	9.479	182	152	0.024
100	9.66	10.352	191	156	0.029
100	8.38	11.933	199	161	0.032
100	7.75	12.903	209	166	0.037
100	7.46	13.405	216	170	0.040
100	6.63	15.083	224	175	0.043
100	6.05	16.529	230	177	0.047
100	5.36	18.657	238	182	0.050
100	5.13	19.493	245	185	0.054
100	4.83	20.704	255	189	0.060
100	4.62	21.645	260	193	0.061
100	4.42	22.624	267	197	0.064
100	4.12	24.272	274	195	0.073
100	3.41	29.326	293	203	0.084

6.0 mm Square Staggered Steel Screen

PARTIALLY BLINDED - Submerged (b)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	33.69	2.968	194	187	0.001
100	24.02	4.163	204	195	0.003
100	18.57	5.385	211	200	0.005
100	15.50	6.452	218	205	0.007
100	12.51	7.994	227	211	0.010
100	10.72	9.328	236	217	0.013
100	9.72	10.288	243	221	0.016
100	8.33	12.005	251	227	0.018
100	7.92	12.626	258	231	0.021
100	6.69	14.948	266	236	0.024
100	6.34	15.773	274	241	0.027
100	5.92	16.892	281	245	0.030
100	5.29	18.904	287	247	0.034
100	5.17	19.342	294	252	0.036
100	4.84	20.661	301	255	0.040
100	4.67	21.413	309	260	0.043
100	4.45	22.472	316	264	0.046
100	4.22	23.697	321	266	0.049

PARTIALLY BLINDED - Submerged (c)

Volume (litres)	Time (secs)	Discharge (l/s)	Upstream Depth (mm)	Downstream Depth (mm)	Head Loss (m)
0	0.00	0.000	38	32	0.000
100	33.66	2.971	241	235	0.000
100	23.70	4.219	249	242	0.001
100	18.70	5.348	257	248	0.003
100	15.87	6.301	265	255	0.004
100	12.81	7.806	273	261	0.006
100	10.89	9.183	281	267	0.008
100	9.21	10.858	289	272	0.011
100	8.82	11.338	295	276	0.013
100	7.90	12.658	301	281	0.014
100	6.83	14.641	309	286	0.017
100	6.68	14.970	317	291	0.020
100	6.38	15.674	323	295	0.022
100	5.62	17.794	330	299	0.025
100	5.28	18.939	336	303	0.027
100	5.11	19.569	342	308	0.028

6.0 mm Square Plastic Mesh; Copasac (74% Open Area)

CLEAN (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0026	0.030	68	0.228	1.612
0.0044	0.035	80	0.301	1.612
0.0058	0.041	92	0.314	1.612
0.0070	0.045	102	0.328	1.612
0.0078	0.057	115	0.289	1.612
0.0090	0.065	125	0.286	1.612
0.0104	0.101	135	0.246	1.612
0.0119	0.108	145	0.254	1.612
0.0124	0.115	154	0.242	1.612
0.0146	0.120	162	0.264	1.612
0.0160	0.125	169	0.272	1.612
0.0167	0.129	176	0.269	1.612
0.0186	0.135	185	0.278	1.612
0.0188	0.142	194	0.261	1.612
0.0204	0.146	201	0.271	1.612
0.0220	0.152	209	0.274	1.612
0.0230	0.157	216	0.274	1.612
0.0239	0.163	223	0.270	1.612
0.0269	0.169	232	0.287	1.612

CLEAN (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0028	0.001	103	0.886	1.612
0.0043	0.002	113	0.864	1.612
0.0052	0.003	119	0.812	1.612
0.0067	0.004	127	0.846	1.612
0.0082	0.006	136	0.791	1.612
0.0095	0.008	142	0.760	1.612
0.0105	0.009	150	0.751	1.612
0.0119	0.011	156	0.740	1.612
0.0133	0.013	162	0.732	1.612
0.0142	0.015	169	0.698	1.612
0.0156	0.016	174	0.720	1.612
0.0161	0.017	180	0.696	1.612
0.0177	0.020	186	0.683	1.612
0.0199	0.022	192	0.711	1.612
0.0212	0.022	197	0.737	1.612
0.0218	0.024	202	0.708	1.612
0.0234	0.027	208	0.697	1.612
0.0257	0.030	213	0.709	1.612
0.0270	0.031	224	0.697	1.612

6.0 mm Square Plastic Mesh; Copasac (74% Open Area)
CLEAN (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0031	0.000	168	-	-
0.0041	0.000	176	-	-
0.0053	0.000	183	-	-
0.0069	0.001	190	1.166	1.612
0.0081	0.003	197	0.764	1.612
0.0095	0.003	204	0.860	1.612
0.0100	0.004	210	0.769	1.612
0.0122	0.004	215	0.909	1.612
0.0131	0.006	222	0.773	1.612
0.0141	0.007	227	0.756	1.612
0.0157	0.008	232	0.771	1.612
0.0167	0.009	237	0.754	1.612
0.0177	0.009	243	0.782	1.612
0.0194	0.010	248	0.795	1.612
0.0199	0.012	253	0.731	1.612
0.0223	0.012	258	0.803	1.612
0.0224	0.015	263	0.708	1.612
0.0238	0.016	269	0.710	1.612
0.0290	0.018	285	0.771	1.612

CLEAN (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.000	218	-	-
0.0042	0.000	225	-	-
0.0054	0.000	233	-	-
0.0068	0.001	240	0.906	1.612
0.0080	0.001	247	1.042	1.612
0.0098	0.002	253	0.879	1.612
0.0105	0.002	258	0.928	1.612
0.0118	0.003	264	0.830	1.612
0.0132	0.003	269	0.909	1.612
0.0147	0.004	275	0.857	1.612
0.0162	0.004	280	0.931	1.612
0.0171	0.005	285	0.861	1.612
0.0181	0.006	290	0.822	1.612
0.0184	0.007	295	0.759	1.612
0.0200	0.007	300	0.812	1.612

6.0 mm Round Perforated Polyurethane Screen (49% Open Area)

CLEAN (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	
0.0027	0.008	54	0.868	1.346
0.0047	0.011	69	0.993	1.346
0.0053	0.012	76	0.982	1.346
0.0069	0.015	85	1.024	1.346
0.0078	0.017	93	0.989	1.346
0.0096	0.019	101	1.060	1.346
0.0108	0.020	108	1.085	1.346
0.0121	0.022	115	1.086	1.346
0.0136	0.024	122	1.106	1.346
0.0139	0.026	129	1.024	1.346
0.0156	0.027	135	1.080	1.346
0.0173	0.028	141	1.126	1.346
0.0177	0.033	147	1.020	1.346
0.0181	0.035	153	0.974	1.346
0.0209	0.036	160	1.058	1.346
0.0225	0.037	165	1.087	1.346
0.0230	0.038	172	1.055	1.346
0.0247	0.037	176	1.120	1.346
0.0273	0.040	188	1.116	1.346

CLEAN (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	
0.0030	0.001	104	1.383	1.346
0.0043	0.002	112	1.318	1.346
0.0055	0.003	120	1.282	1.346
0.0065	0.004	127	1.238	1.346
0.0080	0.005	135	1.286	1.346
0.0096	0.006	142	1.344	1.346
0.0103	0.008	149	1.190	1.346
0.0123	0.009	155	1.285	1.346
0.0134	0.010	160	1.288	1.346
0.0141	0.011	166	1.242	1.346
0.0155	0.013	172	1.216	1.346
0.0167	0.013	176	1.278	1.346
0.0180	0.016	182	1.202	1.346
0.0189	0.016	187	1.230	1.346
0.0206	0.018	192	1.229	1.346
0.0230	0.020	197	1.270	1.346
0.0238	0.020	201	1.283	1.346
0.0239	0.023	206	1.173	1.346
0.0268	0.024	214	1.242	1.346

6.0 mm Round Perforated Polyurethane Screen (49% Open Area)

CLEAN (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	
0.0029	0.000	167	-	1.346
0.0043	0.001	175	-	1.346
0.0054	0.001	183	-	1.346
0.0068	0.002	190	1.233	1.346
0.0081	0.002	195	1.423	1.346
0.0092	0.003	202	1.283	1.346
0.0106	0.003	207	1.436	1.346
0.0114	0.004	213	1.294	1.346
0.0126	0.005	219	1.246	1.346
0.0144	0.006	224	1.274	1.346
0.0154	0.006	229	1.332	1.346
0.0164	0.006	234	1.391	1.346
0.0175	0.008	239	1.260	1.346
0.0198	0.009	244	1.314	1.346
0.0214	0.009	248	1.395	1.346
0.0225	0.010	253	1.367	1.346
0.0231	0.011	258	1.314	1.346
0.0238	0.011	262	1.331	1.346
0.0275	0.012	273	1.411	1.346

CLEAN (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	
0.0029	0.000	211	-	
0.0047	0.000	220	-	
0.0054	0.000	226	-	
0.0068	0.001	233	1.412	1.346
0.0081	0.002	240	1.160	1.346
0.0090	0.002	247	1.246	1.346
0.0105	0.003	252	1.170	1.346
0.0117	0.004	257	1.103	1.346
0.0127	0.005	263	1.048	1.346
0.0142	0.005	267	1.159	1.346
0.0168	0.006	274	1.216	1.346
0.0169	0.008	278	1.045	1.346
0.0178	0.008	282	1.085	1.346
0.0192	0.009	287	1.081	1.346
0.0203	0.010	291	1.071	1.346

6.4 mm Round Perforated Steel Screen (43% Open Area)

CLEAN (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0026	0.012	58	0.705	0.906
0.0044	0.018	75	0.766	0.906
0.0057	0.022	85	0.785	0.906
0.0067	0.027	95	0.756	0.906
0.0081	0.031	107	0.748	0.906
0.0091	0.035	117	0.728	0.906
0.0106	0.040	126	0.736	0.906
0.0116	0.042	135	0.733	0.906
0.0134	0.047	144	0.748	0.906
0.0146	0.053	153	0.724	0.906
0.0158	0.057	160	0.723	0.906
0.0169	0.058	168	0.732	0.906
0.0176	0.059	176	0.721	0.906
0.0186	0.061	184	0.716	0.906
0.0207	0.069	192	0.717	0.906
0.0227	0.073	199	0.740	0.906
0.0233	0.080	207	0.695	0.906
0.0245	0.088	212	0.682	0.906
0.0269	0.100	224	0.664	0.906

CLEAN (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.002	107	1.059	0.906
0.0041	0.005	117	0.862	0.906
0.0055	0.007	126	0.914	0.906
0.0064	0.009	133	0.894	0.906
0.0078	0.012	142	0.878	0.906
0.0091	0.016	153	0.824	0.906
0.0103	0.019	160	0.818	0.906
0.0121	0.021	167	0.874	0.906
0.0132	0.024	175	0.855	0.906
0.0140	0.027	183	0.814	0.906
0.0160	0.031	191	0.831	0.906
0.0160	0.032	199	0.788	0.906
0.0179	0.036	204	0.810	0.906
0.0186	0.041	213	0.753	0.906
0.0209	0.041	220	0.820	0.906
0.0221	0.047	225	0.794	0.906
0.0239	0.053	231	0.785	0.906
0.0246	0.059	238	0.746	0.906
0.0248	0.065	245	0.694	0.906

6.4 mm Round Perforated Steel Screen (43% Open Area)

CLEAN (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.000	168	-	-
0.0041	0.001	177	-	-
0.0055	0.003	186	-	-
0.0068	0.004	195	0.967	0.906
0.0080	0.005	201	0.985	0.906
0.0090	0.007	208	0.909	0.906
0.0106	0.009	215	0.910	0.906
0.0122	0.010	221	0.966	0.906
0.0130	0.012	228	0.910	0.906
0.0143	0.014	235	0.900	0.906
0.0159	0.016	242	0.910	0.906
0.0168	0.018	248	0.885	0.906
0.0180	0.020	254	0.878	0.906
0.0187	0.022	260	0.850	0.906
0.0210	0.025	266	0.872	0.906
0.0225	0.026	272	0.899	0.906
0.0234	0.029	278	0.866	0.906
0.0251	0.031	284	0.877	0.906
0.0261	0.033	291	0.864	0.906

CLEAN (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0031	0.000	211	-	-
0.0043	0.000	220	-	-
0.0054	0.000	226	-	-
0.0068	0.001	233	1.609	0.906
0.0083	0.002	240	1.355	0.906
0.0093	0.002	247	1.470	0.906
0.0106	0.003	252	1.349	0.906
0.0114	0.004	257	1.225	0.906
0.0141	0.005	263	1.327	0.906
0.0146	0.005	267	1.357	0.906
0.0150	0.006	274	1.238	0.906
0.0164	0.008	278	1.156	0.906
0.0177	0.008	282	1.230	0.906

6.0 mm Square Perforated Steel Screen (62% Open Area)

CLEAN (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0030	0.006	55	0.860	1.226
0.0043	0.007	64	0.966	1.226
0.0055	0.010	73	0.914	1.226
0.0065	0.012	80	0.897	1.226
0.0080	0.013	88	0.973	1.226
0.0092	0.016	97	0.914	1.226
0.0105	0.017	104	0.937	1.226
0.0121	0.018	110	0.998	1.226
0.0124	0.021	117	0.888	1.226
0.0138	0.023	124	0.890	1.226
0.0154	0.024	130	0.930	1.226
0.0162	0.027	137	0.874	1.226
0.0183	0.030	145	0.884	1.226
0.0193	0.031	148	0.897	1.226
0.0209	0.033	154	0.906	1.226
0.0222	0.033	160	0.928	1.226
0.0236	0.032	165	0.972	1.226
0.0238	0.032	171	0.945	1.226
0.0254	0.034	178	0.941	1.226

CLEAN (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0028	0.000	106	0.968	1.226
0.0041	0.002	115	1.212	1.226
0.0054	0.002	122	1.169	1.226
0.0069	0.003	130	1.175	1.226
0.0084	0.004	137	1.276	1.226
0.0094	0.004	142	1.107	1.226
0.0105	0.006	149	1.062	1.226
0.0114	0.007	155	1.263	1.226
0.0139	0.007	160	1.096	1.226
0.0142	0.009	166	1.056	1.226
0.0157	0.011	172	1.114	1.226
0.0169	0.011	176	1.091	1.226
0.0178	0.012	181	1.050	1.226
0.0185	0.013	187	1.073	1.226
0.0208	0.015	192	1.035	1.226
0.0218	0.017	196	0.960	1.226
0.0225	0.020	201	1.063	1.226
0.0243	0.018	207	0.982	1.226
0.0262	0.023	214	0.697	1.226

6.0 mm Square Perforated Steel Screen (62% Open Area)

CLEAN (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.000	170	-	-
0.0041	0.000	176	-	-
0.0055	0.000	184	-	-
0.0067	0.001	191	1.356	1.226
0.0082	0.001	197	1.597	1.226
0.0092	0.002	203	1.225	1.226
0.0109	0.002	209	1.410	1.226
0.0113	0.002	214	1.438	1.226
0.0129	0.004	220	1.127	1.226
0.0147	0.004	225	1.258	1.226
0.0168	0.004	230	1.402	1.226
0.0170	0.005	235	1.242	1.226
0.0176	0.006	240	1.147	1.226
0.0196	0.006	245	1.254	1.226
0.0204	0.008	250	1.108	1.226
0.0226	0.008	254	1.206	1.226
0.0228	0.009	260	1.121	1.226
0.0246	0.010	263	1.137	1.226
0.0277	0.011	270	1.187	1.226

CLEAN (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0028	0.000	217	-	-
0.0042	0.000	226	-	-
0.0055	0.000	232	-	-
0.0066	0.001	239	1.064	1.226
0.0081	0.001	244	1.282	1.226
0.0095	0.001	251	1.451	1.226
0.0108	0.001	257	1.613	1.226
0.0122	0.001	262	1.784	1.226
0.0132	0.002	267	1.346	1.226
0.0143	0.002	272	1.428	1.226
0.0154	0.003	277	1.235	1.226
0.0168	0.003	282	1.323	1.226
0.0181	0.004	287	1.211	1.226
0.0199	0.004	291	1.314	1.226
0.0208	0.004	295	1.355	1.226

6.0 mm Square Staggered Perforated Steel Screen (52% Open Area)

CLEAN (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0031	0.010	60	0.736	1.031
0.0043	0.013	71	0.768	1.031
0.0058	0.016	80	0.825	1.031
0.0067	0.019	89	0.791	1.031
0.0083	0.022	99	0.818	1.031
0.0094	0.025	106	0.813	1.031
0.0107	0.027	115	0.821	1.031
0.0118	0.031	123	0.786	1.031
0.0133	0.033	131	0.811	1.031
0.0147	0.036	138	0.814	1.031
0.0155	0.038	145	0.794	1.031
0.0169	0.042	152	0.786	1.031
0.0180	0.045	159	0.772	1.031
0.0207	0.046	166	0.842	1.031
0.0213	0.047	172	0.826	1.031
0.0236	0.048	178	0.877	1.031
0.0238	0.049	185	0.839	1.031
0.0240	0.053	192	0.787	1.031
0.0315	0.057	199	0.961	1.031

CLEAN (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0028	0.002	105	0.868	1.031
0.0040	0.003	113	0.945	1.031
0.0053	0.004	121	1.007	1.031
0.0063	0.007	128	0.857	1.031
0.0078	0.008	135	0.934	1.031
0.0097	0.011	143	0.933	1.031
0.0108	0.013	151	0.912	1.031
0.0121	0.013	155	0.990	1.031
0.0124	0.016	162	0.874	1.031
0.0143	0.019	169	0.890	1.031
0.0151	0.021	175	0.863	1.031
0.0171	0.022	181	0.920	1.031
0.0186	0.024	187	0.930	1.031
0.0193	0.027	193	0.881	1.031
0.0203	0.029	197	0.875	1.031
0.0214	0.031	204	0.863	1.031
0.0226	0.032	208	0.878	1.031
0.0246	0.035	213	0.892	1.031
0.0270	0.038	221	0.905	1.031

6.0 mm Square Staggered Perforated Steel Screen (52% Open Area)

CLEAN (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0025	0.000	160	-	-
0.0042	0.001	172	-	-
0.0052	0.002	179	-	-
0.0065	0.002	185	1.141	1.031
0.0079	0.003	193	1.086	1.031
0.0092	0.004	199	1.063	1.031
0.0107	0.005	205	1.067	1.031
0.0117	0.006	211	1.033	1.031
0.0130	0.007	216	1.037	1.031
0.0146	0.009	221	1.006	1.031
0.0152	0.010	225	0.980	1.031
0.0164	0.011	230	0.982	1.031
0.0174	0.013	236	0.935	1.031
0.0198	0.014	241	1.007	1.031
0.0200	0.016	245	0.932	1.031
0.0216	0.017	251	0.955	1.031
0.0235	0.019	255	0.966	1.031
0.0249	0.020	260	0.982	1.031
0.0267	0.023	266	0.957	1.031

CLEAN (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0027	0.000	211	-	-
0.0041	0.000	220	-	-
0.0053	0.000	226	-	-
0.0066	0.001	233	1.304	1.031
0.0079	0.002	240	1.067	1.031
0.0092	0.002	247	1.202	1.031
0.0102	0.003	252	1.073	1.031
0.0120	0.004	257	1.065	1.031
0.0128	0.005	263	0.999	1.031
0.0136	0.005	267	1.046	1.031
0.0152	0.006	274	1.033	1.031
0.0171	0.008	278	0.995	1.031
0.0179	0.008	282	1.028	1.031
0.0192	0.009	287	1.020	1.031
0.0209	0.010	291	1.040	1.031
0.0224	0.012	297	0.997	1.031

6.0 mm Square Plastic Mesh; Copasac (74% Open Area)

PARTIALLY BLINDED (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0032	0.030	63	0.592	0.840
0.0040	0.035	75	0.586	0.840
0.0055	0.041	87	0.638	0.840
0.0062	0.045	97	0.615	0.840
0.0082	0.057	110	0.634	0.840
0.0093	0.065	120	0.615	0.840
0.0104	0.101	130	0.512	0.840
0.0120	0.108	140	0.530	0.840
0.0131	0.115	149	0.526	0.840
0.0134	0.120	157	0.503	0.840
0.0152	0.125	164	0.535	0.840
0.0167	0.129	171	0.552	0.840
0.0175	0.135	180	0.538	0.840
0.0187	0.142	189	0.535	0.840
0.0200	0.146	196	0.543	0.840
0.0215	0.152	204	0.549	0.840
0.0233	0.157	211	0.567	0.840
0.0248	0.163	218	0.573	0.840
0.0271	0.169	227	0.591	0.840

PARTIALLY BLINDED (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.004	92	1.030	0.840
0.0042	0.009	103	0.879	0.840
0.0053	0.012	112	0.871	0.840
0.0065	0.017	123	0.830	0.840
0.0079	0.021	134	0.832	0.840
0.0089	0.026	144	0.781	0.840
0.0102	0.029	152	0.803	0.840
0.0115	0.032	160	0.821	0.840
0.0130	0.037	168	0.815	0.840
0.0139	0.041	177	0.790	0.840
0.0155	0.044	185	0.810	0.840
0.0175	0.049	193	0.832	0.840
0.0185	0.053	201	0.814	0.840
0.0199	0.056	209	0.818	0.840
0.0204	0.061	217	0.773	0.840
0.0215	0.063	223	0.780	0.840
0.0246	0.070	231	0.820	0.840
0.0248	0.074	238	0.780	0.840
0.0269	0.076	247	0.803	0.840

6.0 mm Square Plastic Mesh; Copasac (74% Open Area)
PARTIALLY BLINDED (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0032	0.000	150	-	-
0.0044	0.003	162	1.017	0.840
0.0057	0.006	172	0.868	0.840
0.0070	0.008	180	0.879	0.840
0.0079	0.010	187	0.857	0.840
0.0095	0.013	196	0.867	0.840
0.0109	0.015	204	0.889	0.840
0.0116	0.018	211	0.833	0.840
0.0128	0.021	218	0.824	0.840
0.0142	0.024	225	0.826	0.840
0.0149	0.026	232	0.809	0.840
0.0163	0.029	239	0.817	0.840
0.0178	0.032	247	0.818	0.840
0.0189	0.037	255	0.785	0.840
0.0208	0.039	262	0.817	0.840
0.0221	0.042	267	0.821	0.840
0.0240	0.045	275	0.838	0.840
0.0248	0.049	282	0.808	0.840
0.0267	0.051	289	0.831	0.840

PARTIALLY BLINDED (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.000	199	-	-
0.0044	0.001	210	1.356	0.840
0.0057	0.004	220	0.829	0.840
0.0068	0.005	226	0.870	0.840
0.0087	0.007	236	0.898	0.840
0.0092	0.009	243	0.812	0.840
0.0099	0.011	250	0.771	0.840
0.0114	0.013	256	0.794	0.840
0.0128	0.014	263	0.834	0.840
0.0137	0.017	270	0.790	0.840
0.0159	0.019	278	0.845	0.840
0.0169	0.021	284	0.833	0.840
0.0169	0.023	290	0.782	0.840
0.0190	0.026	297	0.809	0.840
0.0208	0.027	302	0.852	0.840

6.0 mm Round Perforated Polyurethane Screen (49% Open Area)

PARTIALLY BLINDED (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	76	-	
0.0026	0.049	96	0.478	0.970
0.0042	0.053	111	0.583	0.970
0.0052	0.063	123	0.577	0.970
0.0065	0.071	138	0.607	0.970
0.0078	0.079	148	0.614	0.970
0.0093	0.095	161	0.624	0.970
0.0102	0.126	169	0.551	0.970
0.0116	0.131	182	0.582	0.970
0.0132	0.142	192	0.590	0.970
0.0147	0.149	202	0.611	0.970
0.0152	0.157	214	0.585	0.970
0.0169	0.169	224	0.592	0.970
0.0186	0.177	232	0.607	0.970
0.0197	0.183	244	0.610	0.970
0.0209	0.190	252	0.604	0.970
0.0222	0.194	261	0.615	0.970
0.0229	0.200	269	0.602	0.970
0.0239	0.207	300	0.600	0.970
0.0304	0.238	227	0.638	0.970

PARTIALLY BLINDED (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	
0.0030	0.011	104	0.836	0.970
0.0046	0.016	114	0.982	0.970
0.0054	0.024	130	0.822	0.970
0.0065	0.028	138	0.864	0.970
0.0089	0.035	151	0.967	0.970
0.0093	0.041	162	0.869	0.970
0.0102	0.046	171	0.855	0.970
0.0117	0.050	180	0.896	0.970
0.0130	0.058	192	0.863	0.970
0.0140	0.063	201	0.852	0.970
0.0155	0.068	211	0.865	0.970
0.0165	0.075	221	0.839	0.970
0.0174	0.079	229	0.828	0.970
0.0187	0.084	239	0.829	0.970
0.0223	0.090	249	0.918	0.970
0.0229	0.097	259	0.873	0.970
0.0233	0.102	267	0.840	0.970
0.0242	0.106	276	0.828	0.970
0.0262	0.118	295	0.793	0.970

6.0 mm Round Perforated Polyurethane Screen (49% Open Area)

PARTIALLY BLINDED (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	0.970
0.0029	0.005	160	-	0.970
0.0041	0.007	169	0.896	0.970
0.0054	0.011	179	0.878	0.970
0.0064	0.016	189	0.827	0.970
0.0082	0.021	200	0.867	0.970
0.0094	0.025	209	0.870	0.970
0.0107	0.030	220	0.860	0.970
0.0116	0.034	229	0.843	0.970
0.0130	0.040	239	0.836	0.970
0.0146	0.044	248	0.863	0.970
0.0149	0.050	258	0.796	0.970
0.0160	0.053	265	0.806	0.970
0.0180	0.059	275	0.826	0.970
0.0194	0.062	282	0.848	0.970
0.0215	0.068	293	0.863	0.970
0.0221	0.068	302	0.861	0.970

PARTIALLY BLINDED (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	0.970
0.0029	0.002	207	-	0.970
0.0042	0.006	218	0.759	0.970
0.0053	0.009	226	0.758	0.970
0.0067	0.012	235	0.795	0.970
0.0077	0.016	245	0.765	0.970
0.0091	0.020	255	0.772	0.970
0.0105	0.024	263	0.791	0.970
0.0116	0.027	271	0.800	0.970
0.0126	0.031	280	0.788	0.970
0.0140	0.036	289	0.786	0.970
0.0150	0.041	299	0.762	0.970

6.4 mm Round Perforated Steel Screen (43% Open Area)

PARTIALLY BLINDED (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0030	0.030	62	0.538	0.857
0.0041	0.058	76	0.435	0.857
0.0055	0.068	90	0.453	0.857
0.0066	0.078	101	0.456	0.857
0.0080	0.088	112	0.469	0.857
0.0090	0.097	124	0.454	0.857
0.0108	0.105	136	0.477	0.857
0.0117	0.111	145	0.472	0.857
0.0125	0.117	152	0.468	0.857
0.0140	0.125	164	0.471	0.857
0.0149	0.130	171	0.471	0.857
0.0168	0.137	181	0.488	0.857
0.0179	0.141	189	0.489	0.857
0.0187	0.150	199	0.472	0.857
0.0193	0.152	205	0.469	0.857
0.0223	0.157	213	0.514	0.857
0.0230	0.164	222	0.498	0.857
0.0248	0.167	227	0.519	0.857
0.0254	0.175	240	0.493	0.857

PARTIALLY BLINDED (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.004	92	0.979	0.857
0.0043	0.008	103	0.917	0.857
0.0054	0.012	113	0.853	0.857
0.0066	0.015	122	0.858	0.857
0.0079	0.020	133	0.813	0.857
0.0095	0.024	143	0.832	0.857
0.0108	0.029	153	0.808	0.857
0.0120	0.031	160	0.826	0.857
0.0129	0.037	170	0.767	0.857
0.0142	0.040	178	0.777	0.857
0.0149	0.044	186	0.745	0.857
0.0168	0.048	194	0.770	0.857
0.0175	0.051	202	0.747	0.857
0.0184	0.057	210	0.713	0.857
0.0199	0.059	216	0.738	0.857
0.0211	0.067	227	0.697	0.857
0.0242	0.069	233	0.769	0.857
0.0248	0.071	240	0.753	0.857
0.0269	0.077	254	0.742	0.857

6.4 mm Round Perforated Steel Screen (43% Open Area)

PARTIALLY BLINDED (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0031	0.000	151	-	-
0.0042	0.001	162	1.610	0.857
0.0053	0.003	169	1.106	0.857
0.0065	0.005	177	1.008	0.857
0.0079	0.008	186	0.918	0.857
0.0098	0.011	195	0.928	0.857
0.0105	0.013	203	0.885	0.857
0.0117	0.016	210	0.858	0.857
0.0136	0.019	218	0.883	0.857
0.0146	0.021	225	0.871	0.857
0.0150	0.024	232	0.814	0.857
0.0164	0.027	240	0.808	0.857
0.0174	0.030	247	0.792	0.857
0.0192	0.034	255	0.794	0.857
0.0205	0.038	262	0.782	0.857
0.0206	0.040	268	0.748	0.857
0.0238	0.042	275	0.820	0.857
0.0240	0.046	281	0.776	0.857
0.0289	0.053	295	0.828	0.857

PARTIALLY BLINDED (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0030	0.000	202	-	-
0.0042	0.000	210	-	-
0.0054	0.001	217	1.536	0.857
0.0066	0.002	224	1.276	0.857
0.0079	0.004	233	1.041	0.857
0.0095	0.007	242	0.911	0.857
0.0101	0.008	248	0.885	0.857
0.0113	0.010	255	0.864	0.857
0.0134	0.012	261	0.914	0.857
0.0141	0.015	269	0.830	0.857
0.0155	0.018	277	0.812	0.857
0.0161	0.019	282	0.807	0.857
0.0178	0.022	290	0.804	0.857
0.0193	0.026	298	0.783	0.857
0.0201	0.027	303	0.786	0.857

6.0 mm Square Perforated Steel Screen (62% Open Area)

PARTIALLY BLINDED (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.020	52	0.708	0.889
0.0042	0.026	68	0.695	0.889
0.0055	0.032	80	0.693	0.889
0.0068	0.033	86	0.784	0.889
0.0078	0.045	100	0.666	0.889
0.0092	0.045	108	0.727	0.889
0.0104	0.048	116	0.739	0.889
0.0119	0.050	124	0.780	0.889
0.0133	0.057	135	0.746	0.889
0.0145	0.059	142	0.762	0.889
0.0161	0.067	150	0.750	0.889
0.0162	0.070	157	0.706	0.889
0.0176	0.071	163	0.734	0.889
0.0191	0.072	172	0.751	0.889
0.0205	0.067	180	0.797	0.889
0.0219	0.071	186	0.802	0.889
0.0229	0.071	193	0.806	0.889
0.0235	0.073	199	0.793	0.889
0.0271	0.082	212	0.809	0.889

PARTIALLY BLINDED (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0031	0.003	92	1.099	0.889
0.0039	0.006	100	0.911	0.889
0.0051	0.010	110	0.845	0.889
0.0066	0.013	121	0.866	0.889
0.0077	0.017	130	0.822	0.889
0.0093	0.020	139	0.860	0.889
0.0102	0.022	147	0.845	0.889
0.0120	0.026	154	0.874	0.889
0.0124	0.028	161	0.832	0.889
0.0141	0.032	171	0.833	0.889
0.0150	0.035	178	0.818	0.889
0.0176	0.037	185	0.896	0.889
0.0178	0.040	190	0.850	0.889
0.0187	0.044	197	0.818	0.889
0.0202	0.046	205	0.832	0.889
0.0213	0.049	211	0.825	0.889
0.0231	0.055	219	0.816	0.889
0.0235	0.059	225	0.780	0.889
0.0268	0.062	235	0.830	0.889

6.0 mm Square Perforated Steel Screen (62% Open Area)

PARTIALLY BLINDED (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0028	0.000	190	-	-
0.0042	0.002	202	1.052	0.889
0.0055	0.004	211	0.916	0.889
0.0067	0.005	217	0.965	0.889
0.0079	0.007	226	0.917	0.889
0.0091	0.009	233	0.897	0.889
0.0106	0.011	242	0.904	0.889
0.0120	0.014	249	0.883	0.889
0.0128	0.015	255	0.882	0.889
0.0136	0.018	262	0.830	0.889
0.0152	0.021	269	0.830	0.889
0.0174	0.022	275	0.904	0.889
0.0179	0.026	282	0.832	0.889
0.0197	0.027	288	0.877	0.889
0.0207	0.031	295	0.834	0.889
0.0214	0.033	301	0.816	0.889
0.0229	0.035	306	0.835	0.889
0.0241	0.037	312	0.834	0.889
0.0267	0.042	325	0.827	0.889

PARTIALLY BLINDED (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.000	202	-	-
0.0043	0.001	211	1.163	0.889
0.0055	0.001	218	1.437	0.889
0.0065	0.003	227	0.941	0.889
0.0084	0.005	235	0.919	0.889
0.0091	0.006	241	0.879	0.889
0.0102	0.009	249	0.783	0.889
0.0112	0.010	255	0.793	0.889
0.0126	0.011	261	0.836	0.889
0.0140	0.013	267	0.836	0.889
0.0153	0.015	275	0.825	0.889
0.0166	0.018	282	0.795	0.889
0.0179	0.020	288	0.796	0.889
0.0193	0.022	293	0.803	0.889
0.0207	0.024	300	0.809	0.889

6.0 mm Square Staggered Perforated Steel Screen (52% Open Area)

PARTIALLY BLINDED (Free Flow)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0029	0.035	64	0.592	0.785
0.0044	0.038	79	0.693	0.785
0.0054	0.043	91	0.688	0.785
0.0067	0.048	101	0.733	0.785
0.0081	0.065	113	0.681	0.785
0.0092	0.064	124	0.709	0.785
0.0103	0.068	131	0.729	0.785
0.0114	0.067	139	0.762	0.785
0.0129	0.077	149	0.752	0.785
0.0146	0.107	160	0.675	0.785
0.0153	0.076	165	0.813	0.785
0.0176	0.119	175	0.703	0.785
0.0179	0.133	183	0.648	0.785
0.0184	0.140	192	0.618	0.785
0.0194	0.148	201	0.606	0.785
0.0231	0.151	205	0.699	0.785
0.0237	0.157	213	0.677	0.785
0.0251	0.165	223	0.669	0.785
0.0278	0.180	243	0.650	0.785

PARTIALLY BLINDED (Submerged One)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0026	0.006	96	0.850	0.785
0.0039	0.011	107	0.835	0.785
0.0053	0.014	117	0.918	0.785
0.0065	0.018	127	0.917	0.785
0.0080	0.023	137	0.927	0.785
0.0095	0.024	144	1.025	0.785
0.0104	0.029	153	0.958	0.785
0.0119	0.032	161	0.999	0.785
0.0129	0.037	171	0.946	0.785
0.0134	0.040	178	0.908	0.785
0.0151	0.043	186	0.943	0.785
0.0165	0.047	192	0.958	0.785
0.0187	0.050	200	1.006	0.785
0.0195	0.054	207	0.977	0.785
0.0207	0.060	217	0.939	0.785
0.0216	0.061	222	0.952	0.785
0.0226	0.064	229	0.942	0.785
0.0243	0.073	236	0.918	0.785
0.0293	0.084	255	0.957	0.785

6.0 mm Square Staggered Perforated Steel Screen (52% Open Area)

PARTIALLY BLINDED (Submerged Two)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0030	0.001	156	-	-
0.0042	0.003	166	1.451	0.785
0.0054	0.005	173	1.104	0.785
0.0065	0.007	180	1.062	0.785
0.0080	0.010	189	1.033	0.785
0.0093	0.013	198	1.020	0.785
0.0103	0.016	205	0.997	0.785
0.0120	0.018	213	0.957	0.785
0.0126	0.021	220	1.013	0.785
0.0149	0.024	228	0.955	0.785
0.0158	0.027	236	1.021	0.785
0.0169	0.030	243	0.981	0.785
0.0189	0.034	249	0.968	0.785
0.0193	0.036	256	0.993	0.785
0.0207	0.040	263	0.960	0.785
0.0214	0.043	271	0.947	0.785
0.0225	0.046	278	0.919	0.785
0.0237	0.049	283	0.909	0.785
0.0267	0.051	289	0.912	0.785

PARTIALLY BLINDED (Submerged Three)

Discharge (m^3/s)	Head Loss (m)	Upstream Depth (mm)	Cd	Calc. Cd
0.0000	0.000	0	-	-
0.0030	0.000	203	-	-
0.0042	0.001	211	1.525	0.785
0.0053	0.003	219	1.075	0.785
0.0063	0.004	227	1.059	0.785
0.0078	0.006	235	1.034	0.785
0.0092	0.008	243	1.019	0.785
0.0109	0.011	251	0.995	0.785
0.0113	0.013	257	0.933	0.785
0.0127	0.014	263	0.981	0.785
0.0146	0.017	271	0.999	0.785
0.0150	0.020	279	0.915	0.785
0.0157	0.022	285	0.894	0.785
0.0178	0.025	292	0.930	0.785
0.0189	0.027	298	0.933	0.785
0.0196	0.028	304	0.928	0.785