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48.1 INTRODUCTION

48.1.1 The Problem

Malaysian cities and towns use the *separate* sewer system, in which wastewater is conveyed in separate pipes from the stormwater drainage system. The alternative, *combined system*, is used in older cities in parts of Europe and North America. The combined system is not favoured for new construction.

(a) Wet Weather Inflows

Even in a "separate" sewer system it is often found that significant amounts of stormwater runoff enter the system during wet weather. These wet weather flows may overload the sewer, causing it to overflow. Because the overflow is a mixture of wastewater and stormwater it is usually offensive and has an adverse impact on stormwater and river water quality.

Typical sources of wet weather inflow into separate sewer systems include the following (see Figure 48.1):

- unintended connection of roof and stormwater to the sewer system. This may be caused by poor plumbing practices or illegal connections.
- old, cracked or damaged sewer pipes and manholes.
- faulty pipe joints. In some areas the growth of tree roots, which seek out water, may penetrate and damage sewer pipe joints.
- flooding of sewer manholes, allowing floodwater to enter through the manhole lid.
- faulty house service lines (the connection between the property and the sewer). Experience in the USA and Australia is that these contribute about 50% of the total inflow/infiltration; and that they are very difficult to rectify.

Note that pressure pipes such as force mains from pumping stations, are not subject to inflow.

The amount of wet weather inflow may vary widely from one region to another. It is typically a function of the age of the sewer system, the type of pipes used, ground conditions and maintenance practices. In areas with a serious wet weather flow problem, the volumes and quantities of wet weather overflows would be similar to those from a combined sewer overflow (CSO).

Some of the sources of excessive wet weather inflow to sewers can equally well lead to exfiltration – for example cracked pipes or faulty joints. Wastewater exfiltration is likely to have an adverse impact on the quality of groundwater.

(b) Overflows

Once wet weather flow has entered the sewerage system, it forms part of the total wastewater flow and it may surcharge or overflow further downstream.

Separate sewers are normally designed with an allowance for wet weather flow. However, the standard allowance may not be sufficient to accommodate the actual wet weather flow.

The first effect will be to cause a sewer surcharge, where the hydraulic grade line is above the pipe obvert. Because gravity sewer pipes are not normally designed for surcharge, this may cause damage and leaks. In flat areas cases surcharge also may cause back-flooding and wastewater discharges in private property.

If the wet weather flow increases further it will cause overflows. Some sewer systems are designed with formal overflow points. These are shown on the design plans. However if there are no formal overflow points, overflows may still occur through manholes at low points in the system. Pumping stations are usually designed with overflows, which act in the event of pump failure. These stations are a common source of water weather overflows due to insufficient pump capacity. Bypasses at the inlet to a treatment plant or oxidation pond are other examples of wet weather overflows.

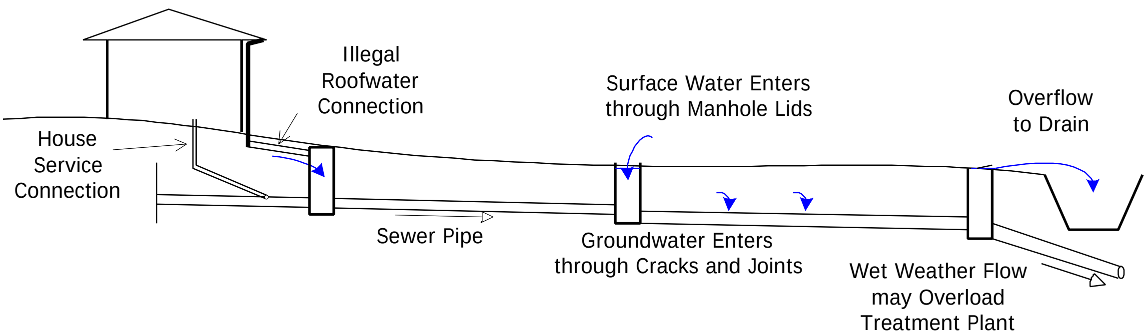

Figure 48.1 Wet Weather Flow in Sewers

48.1.2 The Purpose of this Chapter

Wastewater overflows are included in this Manual because they have a direct effect on stormwater systems. The responsibility for addressing these effects will normally be with the private or government agency responsible for the wastewater system. Inter-agency cooperation is essential for a successful resolution of the problems.

In this Chapter the impact of wet weather wastewater overflows on stormwater quality is discussed. Methods of reducing the problem by source reduction, storage and treatment of overflows are briefly described.

The emphasis in this Chapter is on the rectification and retrofitting of *existing* wastewater systems. In accordance with current best practice, new systems should be designed to prevent the occurrence of wastewater overflows unless the Department of Environment grants special exemptions.

48.2 IMPACTS OF WET WEATHER WASTEWATER FLOWS

Excessive wet weather wastewater flows may cause a large number of effects, as follows:

1. discharges of offensive wastewater to the land surface, stormwater drains or rivers, or groundwater;
2. surcharging of sewer pipes, possibly causing structural or joint failure;
3. backflow of wastewater into private or other properties;
4. overloading of wastewater pumping stations;
5. overloading of wastewater treatment plants. Also, the rapid changes in flow rate at a treatment plant cause operational problems with many treatment processes;
6. adverse impacts on receiving water quality due to the above discharges; and
7. *(possible)* increased stormwater flow rates.

Items (2) to (6) are the direct responsibility of the wastewater agency, and will not be discussed further in this Manual.

48.2.1 Impacts on Water Quality

Typical observed concentrations of undiluted wastewater are shown in the second column of Table 48.1. During wet weather, these concentrations are diluted to some extent by stormwater inflow. The resulting concentrations are likely to resemble those in combined sewers, as shown in the third column of the table.

These pollutant concentrations are typically much higher than those found in natural or urban stormwater runoff.

When these pollutants reach a waterway they will have an adverse effect on water quality. Wastewater produces a high BOD, which depresses levels of dissolved oxygen in receiving waterway. In addition there are problems with ammonia (toxicity), solids (which cause sediment oxygen demand, and may contain toxic pollutants such as heavy metals), and faecal bacteria (which impact on public health including recreational use or drinking water use).

Table 48.1 Typical Wastewater Quality
(after Preul, 1996 and Averill et al., 1999)

	Domestic wastewater	Combined wastewater
BOD_5 (mg/L)	220	85
TSS, (mg/L)	220 - 250	155
Faecal coliforms, MPN/ 100 ml	10^4 - 10^5	Not Available
COD (mg/L)	Not Available	250 - 300
Total P (mg/L)	Not Available	1.8 – 3.0

The magnitude of the impact on receiving waterways is a function of the volume and frequency of the wastewater discharge and the flow, degree of dilution and flushing in the receiving waterway.

Small, infrequent discharges to a large, well-flushed waterway may not have a significant impact; however in other cases the impact will be too great to ignore. Water quality modelling can be used to predict the impacts of discharges as described in Chapter 17.

There are numerous published reports on the impact of wastewater system overflows on water quality (for example Mulliss, Revitt & Shutes, 1996). It is apparent from these reports that:

> "... *(downstream of wastewater overflows) during storm conditions several parameters regularly pose a serious threat with regard to the protection of aquatic life* ".

Sudden reductions in dissolved oxygen levels due to high BOD in discharges are a common cause of fish kills. Other ecological impacts can also occur due to wastewater overflows.

Overflows from wastewater systems serving industrial areas may also contain high levels of toxic heavy metals. These toxic metals can produce toxic sediments and have other environmental impacts (see for example Handova, Konicek et al., 1996). Treatment of heavy metals in overflows is virtually impossible and the recommended strategy to control such impacts is an aggressive trade waste control program to eliminate toxic metal discharges from the wastewater system.

Dry Weather Overflows

Dry weather overflows should only occur under exceptional circumstances, such as plant or equipment failure. Dry weather overflows represent a discharge of untreated wastewater to the environment and as such are likely to be highly offensive and environmentally damaging. Wastewater agencies must ensure that their systems have adequate capacity for dry weather flow. Mechanical installations such as pumping stations should be fitted with standby pumps and backup power supplies, if appropriate, to minimise the risk of failure.

Wet Weather Overflows

It has been the practice in the past to tolerate wet weather overflows because they are difficult to control and the discharge is partly diluted by stormwater runoff. With increasing environmental awareness, this is not longer acceptable.

48.2.2 Impacts on Stormwater Flow

At first sight it may be thought that the volume of a wastewater overflow will add to the flow in a stormwater drain. However, the overflow is usually caused by inflow from rainfall which would otherwise cause runoff in the catchment, and therefore there is no net change in total runoff. In any case the rate of overflow discharge is usually small relative to the rate of stormwater runoff.

A rare exception occurs where the sewer system includes large interceptors, which divert or transfer flow from one catchment to another. Overflows from the transfer system may have a very large volume relative to that of the receiving waterway and therefore, a large impact. Such cases may require very costly remedial measures.

48.3 REMEDIATION OF WET WEATHER WASTEWATER OVERFLOW PROBLEMS

Not every wastewater system has overflow problems. Many systems in Malaysia will perform satisfactorily, without any wet weather wastewater overflows. It is also possible for overflows to occur without having any significant impact. The conditions that lead to problems vary greatly across and within wastewater systems.

48.3.1 Role of Regulator

Regulatory controls apply to the activities of wastewater agencies, under the overall control of the Department of Environment (DOE). The DOE licenses discharges from wastewater treatment plants according to effluent water quality criteria.

In the future, consideration could be given to a program of regulating wastewater overflows. The program should be a combination of regulatory controls, and incentives to improve environmental performance. The program can be attached to, and form part of, the wastewater treatment plant licence. There are many overseas examples of the successful implementation of such programs, such as in the US and Australia (NSW EPA Pollution Reduction Programmes).

48.3.2 Role of Wastewater Agency

Reduction of wastewater overflows is the responsibility of the local wastewater agency. In carrying its work, the agency shall co-operate closely with the agency responsible for stormwater drainage.

Wastewater agencies should be represented on River Basin or Catchment Management Committees. As noted previously, inter-agency cooperation is essential for successful resolution of the wet weather problem.

Figure 48.2 summarises the overall approach to control of overflows.

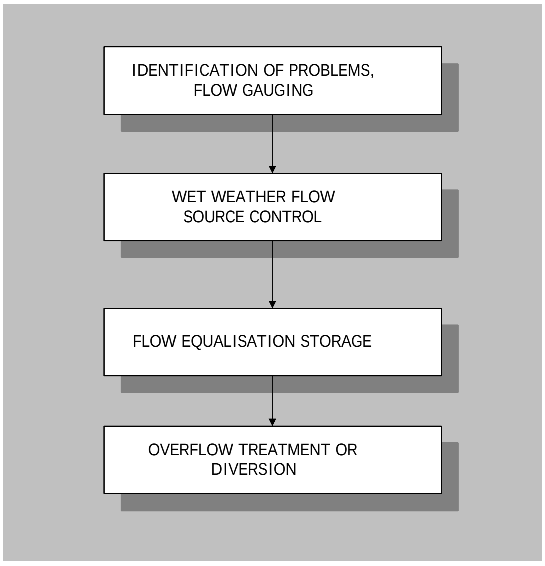

Figure 48.2 Overflow Remediation Process

48.3.3 Identification of Problem

Technology now exists to locate, prevent or control wet weather wastewater overflows. In order that the limited available funds are spent wisely, it is essential to *prioritise* overflow problems. This should be done using the three-stage process set out below.

Stage 1 – Preliminary Desktop Study

Review the information on the system and classify each area with a relative degree of risk, according to the factors in Table 48.2. (Details of the sewerage system should be available from design plans).

Table 48.2 Risk Factors for Wet Weather Overflows

Low Risk of Overflows	High Risk of Overflows
System built after 1970	Old system, built before 1970 (approx.)
Stable population or low rate of growth	Rapid population growth, causing overloaded sewers
Pipe diameter. < 600 mm	Pipe diameter. = 600 mm
Rubber ring or fusion welded pipe joints	Butt or mortar pipe joints
Elevated or sloping land	Low-lying or flood-prone land
Low water table	High water table

The table gives an indication of the risk of overflow *occurrence*. The risk of an overflow having adverse *impacts* should also be evaluated according to the following factors:

- Large river, low environmental sensitivity – *low risk*.
- Sensitive receiving waters e.g. for water supply or environmental protection; low flow rates – *high risk*.

For those systems or parts of systems where the overall risk factors are high, proceed to Stage 2.

Stage 2 – Review Available Data

In this stage a more detailed review of data is undertaken. The following data should be available either by site inspection, environmental monitoring or from the operational records of the wastewater authority.

Any of the following factors may indicate a significant wastewater overflow problem.

- complaints from residents *
- strong sewage odour *
- high *E. Coli* counts in receiving water *
- high level of ammonia and/or BOD in receiving water*
- visible indications e.g. toilet paper, faeces
- pumps running continuously during wet weather
- excessive bypassing of the wastewater treatment plant
- operational problems at the wastewater treatment plant due to changing inflow rates

(* note that the first four factors might also be caused by inadequate treatment at a wastewater treatment plant upstream in the catchment)

For problem areas identified in Stage 1, proceed to Stage 3.

Stage 3 - Flow Gauging

Once the existence of an overflow problem has been confirmed, a wastewater flow gauging program should be undertaken. For this purpose both permanent and temporary gauges are used. The aim is to identify the areas of worst wet weather inflow so that they can be targetted for remedial work. Inflow is usually measured as the ratio of peak wet weather flow to peak dry weather flow. Further details on wet weather flow gauging programs can be found in several references, such as Flinders and Poon (1998).

Gauging programs can be costly to implement. It is outside the scope of this Manual to provide detailed advice on gauging strategies and methods.

Gauging data needs to be interpreted carefully. In general data from large storm events should NOT be used because some flow may have been lost to overflows upstream of the gauge. For this reason gauging may under-estimate the true magnitude of the wet weather flow problem. The most useful data will be derived from small storms of approximately one month to six months average recurrence interval.

A valuable application of flow gauging data is in the calibration of hydraulic models of sewer systems. The aim of this type of study is to relate the wet weather flow to conditions in the catchment, particularly rainfall. Understanding this relationship will give a guide as to the likely sources of wet weather inflow.

48.4 WET WEATHER FLOW SOURCE REDUCTION

Wet weather flow source reduction is the preferred method for controlling the problem of wet weather wastewater flows. By attacking the problem at its source, expenditure on costly pipe and treatment plant amplifications is avoided. In comparison to amplifications, many source control measures are relatively cheap and easily implemented.

This Section provides a brief introduction to the types of source reduction measures available (see Table 48.3). Further information outside the scope of this Manual can be obtained from texts and references on wastewater systems.

48.4.1 Smoke Testing

Incorrect or illicit connections to the sewer can be detected at relatively low cost by implementing a program of smoke testing and rectification.

Smoke testing involves blowing smoke from a smoke generator into a sealed section of sewer, and observing where the smoke exits. This is a simple and economical method of detecting faulty or illegal house service connections.

When a fault is found, a notice is served on the property owner to rectify the connection, at the owner's cost. The wastewater agency may provide workmen to carry out rectification itself. The agency may also choose to subsidise the work, as it will ultimately be to the agency's benefit.

48.4.2 Sewer System Maintenance

For large diameter sewers, 375 mm diameter and above, closed-circuit television (CCTV) inspections should be undertaken. With this equipment a skilled operator can detect such conditions as broken or cracked pipes, tree root penetration and faulty joints.

The temptation to simply close off or seal problem overflows must be resisted. This action should only be taken after a detailed hydraulic analysis of the sewer system, as the closed overflow will redirect flow elsewhere and probably cause other problems.

48.4.3 Sewer Pipe Relining

Replacement of old, damaged or leaking sewer pipes in built-up areas, especially the CBD of large cities, is very difficult and disruptive. In-situ relining of the pipe is a practical alternative (Figure 48.3).

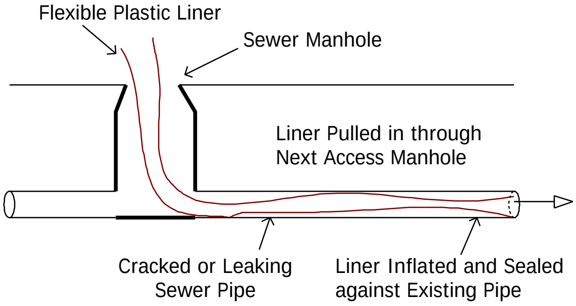

Figure 48.3 Sewer Pipe Relining

Relining may also provide a small increase in flow capacity, as the new lining will usually have a lower frictional resistance than the old pipe.

A number of commercial relining systems are now available. Discussion of sewer rehabilitation is beyond the scope of this Manual and for further details the reader is referred to other specialised publications.

Table 48.3 Wet Weather Flow Source Reduction Techniques

Device or Management Practice	Description	Effectiveness	Implementation
Remove illegal roofwater connections	Smoke testing, reconstruct building connection	High if implemented on a wide scale	Requires public education
Domestic Flow Reduction	Low-flush toilets, flow-saving devices	Limited	Requires public education
Industrial Trade Waste control	Restrictions on quantity and quality of discharge, licensing, pricing	Very high	Wastewater agency in conjunction with industry
Repair faulty house services	Smoke testing, reconstruct house services	High if implemented on a wide scale	Requires public education
Pipe relining	Relining or replacement of pipes which have excessive leakage	High	Wastewater agency
Raise or seal manholes	Reconstruct faulty manhole structures, provide sealed lids in low-lying areas	Very high	Wastewater agency

48.4.4 Flood-Liable Areas

Sewer pipe systems are often located in low-lying or flood-liable areas, or land with a high water table. These areas represent likely source areas for wet weather inflows.

Typical measures that can be adopted by wastewater agencies to control inflow include:

- raising manhole lids above flood level. If this is not practicable, then
- install sealed (watertight) lids, e.g. GATIC™ lids.
- minimise the number of junctions and property service connections in the flood-liable area, as these are potential weak points allowing inflow.
- relining of existing pipes if they are in poor condition.

In very adverse conditions, alternative sewerage systems such as vacuum or pressure systems should be considered. These systems are sealed and therefore, by their design, are not subject to wet weather inflow.

48.5 FLOW EQUALISATION STORAGE

Wet weather overflow events are typically of short duration. Therefore it is practicable to provide storage of the peak flow and then discharge the stored wastewater during a later period of low flow. The principle of peak storage is shown in Figure 48.4.

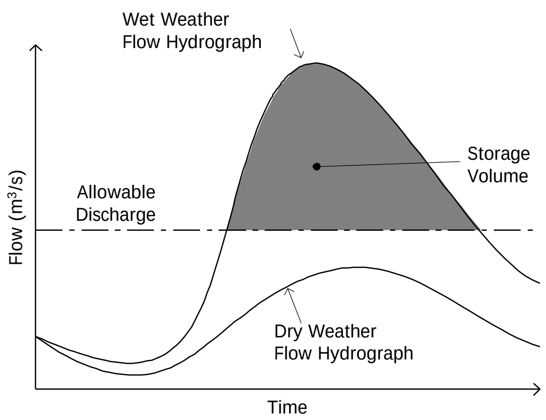

Figure 48.4 Principle of Peak Storage

Overflow storage technology has been developed in Europe and North America for use on combined sewer systems. Nevertheless, similar principles can be applied to wet weather flow in 'separate' sewer systems.

48.5.1 General Considerations

For any form of peak storage, the following general principles should be considered:

- The duration of storage should not exceed 12 to 16 hours unless oxygen injection facilities are provided. Beyond this time the sewage will become septic.
- Mechanical mixing should be provided to reduce settling.
- Storage facilities must be able to be pumped out and cleaned after an impoundment event.

Design of all but the simplest of storage systems should include a full hydraulic analysis taking into account both wastewater flow and storm inflow. A number of suitable computer models are available including MOUSE, XP-SWMM and HydroWorks. Some suitable models are discussed in Chapter 17. As these models are quite complex a trained modeller should undertake the work.

48.5.2 Storage at Pumping Stations

It may be possible to provide additional wet weather storage at a wastewater pumping station, avoiding the need to construct a separate facility. Pumping stations already contain most of the equipment that would be required at a storage facility.

Additional storage can be provided at an existing pumping station by constructing a wet well or chamber beside the existing wet well, with connecting pipes. Pump rates and operating levels should be adjusted accordingly.

Usually the volume of storage that can be achieved at a pump station site is rather limited. Therefore, this method is most applicable for small pumping stations in the upper reaches of a sewerage system.

48.5.3 Purpose-built Storage Facilities

(a) Storage Pipes and Tanks

The use of large-diameter pipes as temporary wastewater storage facilities is practised in combined systems in Japan and Europe. Tanks can also be used for the same purpose. These can be enclosed areas under buildings. The pipes or tanks are arranged to be drained back into the sewer, either by gravity or pumping, after the wet weather peak has passed.

(b) Storage Tunnel

Another useful type of purpose-built storage facility is the deep storage tunnel. With this method a large-diameter tunnel is constructed deep under the city. Wet weather overflows are directed into the tunnel through vertical shafts, and are later pumped out for treatment and discharge. The tunnel can be designed to also act as a transport system, bypassing existing chokes and avoiding the need for costly system amplification within the city streets.

Construction of a very large, deep storage tunnel system was commenced under the northern suburbs of Sydney Australia, in 1999. Similar tunnels exist in Chicago USA, Osaka Japan, and elsewhere.

48.5.4 Real-time Control

Storage facilities can incorporate real-time control (RTC) to optimise the use of the storage volume. Devices such as pumps and movable weirs in the sewer system, can be automatically controlled to temporarily store wet weather flows. Such controls can incorporate computer modelling and flow prediction techniques.

RTC takes advantage of the fact that for most of the time, there is unused storage capacity in the sewer system. Schilling (1996) estimates that in a typical *combined* sewer system around 50% of the total system storage capacity remains unused, and that around 50% of this (i.e. 25% in total) can be utilised in an optimal real-time control strategy. However these data are site-specific and no comparable figures are available for separate systems.

In the same reference, Schilling argues that the future of RTC lies in reducing the overflow pollution *load* rather just volume. For example, it may be preferable to store the most polluted 'first flush' and then allow discharge of the remaining overflow volume. As a theoretical concept this is desirable, but practical applications have yet to be demonstrated.

RTC also has the potential to improve the efficiency of sewerage treatment plants by reducing flow fluctuations.

Extensive research and a small number of practical applications of RTC are now being undertaken in connection with combined sewer systems in Europe. A general conclusion from this research is that:

> *" . . . The improvement (in overflow control due to RTC) . . . would be significant during storm events of smaller size or pronounced spatial and temporal variability " (Ji et al., 1996).*

Real-time control methods require a major effort in gauging and modelling the existing sewer system; design, implementation and operation of the control system. RTC systems usually require a computer model of the wastewater system. As such, even in western countries their application remains limited to a few locations.

48.6 OVERFLOW TREATMENT OR DIVERSION

48.6.1 Treatment Methods

Treatment of wastewater overflows should only be undertaken as a last resort. It is unlikely to be as cost-effective as source control or storage methods.

Treatment of wastewater overflows presents great technical difficulties due to the large peak flow and rapid changes of flow rate. Also, there is no flow at all during dry periods. Normal sewage treatment processes such as activated sludge treatment, cannot cope with the rapid flowrate changes and periods of no flow.

Because of these problems, overflow treatment is generally limited to physical or chemical methods. Many of these methods have been developed in Europe and North America for application to combined sewer overflows (CSOs). Table 48.4 lists some of the available treatment methods for wet weather wastewater overflows.

Table 48.4 Overflow Treatment Methods

Treatment Method	Pollutants Treated	Comment
Screening	Litter, large solids	Fixed screens are prone to blockage. Use enclosed mechanical screens to avoid odour
Grit removal	Solids	High-rate settling, or cyclone
Proprietary devices	Litter, solids	Proprietary designs
Settling	Solids	Can be combined with storage.
Disinfection	Bacteria	Limited effectiveness due to short contact time.
Constructed wetlands	Organics, bacteria	Limited effectiveness due to intermittent flow.

Averill et al. (1999) report that *". . . . pilot scale process development and full-scale demonstration have shown that a process consisting of polymer coagulation and gravity separation of (combined sewer) overflows can produce effluents meeting primary treatment standards"*. Further developments in wet weather overflow treatment can be expected during the life of this Manual.

The technologies, which are suitable for use in overflow treatment at the present date, are not capable of removing dissolved materials or nutrients.

Stormwater storage/settling tanks are used on some combined sewer systems in temperate climates such as the Netherlands (Kluck, 1996). However this technology cannot be simply transposed to Malaysia because of the much more intense rainfalls, and the differences between separate and combined systems.

48.6.2 Proprietary Devices

Several proprietary devices have been developed for application to wastewater overflow treatment. These generally use physical methods treatment methods such as settling, centrifuging. The extent to which they are effective in removing BOD and COD depends on the degree to which these pollutants are attached to settleable particles.

An example of a proprietary treatment device is the Hydro Storm King™, marketed by Hydro Australia (Figure 48.5).

The Hydro Storm King uses hydrodynamic separation and a self cleansing screen to provide control of solids and floatables in sewer overflows. Gross solids, grit, sediment, suspended solids and associated pollutants are removed and discharged to the sewer system. Over 200 Hydro Storm King outlets have been installed worldwide in 1999, treating flows up to 4000 l/s.

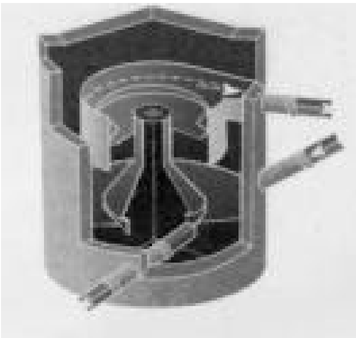

Figure 48.5 Hydro Storm King™ for wastewater overflow control

48.6.3 Diversion

In some cases, the point of discharge of a wastewater overflow may be able to be relocated to another position where it has less impact.

For example, a wastewater overflow that discharges into a stormwater drain may have a serious impact on the amenity of the surrounding community. If grades permit it may be possible to extend the discharge pipe into a nearby river where the river flow will dilute the discharge so that it has a negligible impact.

Obviously this method does not reduce the total pollutant load generated by the wastewater overflow. In sustainability terms, it is a less satisfactory solution than source control.

48.7 OTHER WET WEATHER PROBLEMS IN WASTEWATER SYSTEMS

Two other types of wet weather problems can have a significant effect on wastewater systems. They are direct rainfall on ponds, and flooding of ponds and treatment plants from nearby rivers.

48.7.1 Direct Rainfall

Oxidation ponds are widely used for wastewater treatment in Malaysia. Direct rainfall onto these open ponds may cause them to fill up and overflow, with the consequent spill of pollutants from the ponds into receiving waters.

The solution to this problem is relatively simple, involving raised walls or berms enclosing the ponds to provide temporary wet weather storage. The expected amount of rainfall should be calculated from rainfall records. To provide a reasonable factor of safety the temporary storage volume should be at least sufficient for the 5-days, 1 in 20 year ARI rainfall.

Covering or roofing the ponds is not generally an option because it would impede the oxidation and treatment processes.

Raising of the walls may also assist in protecting the ponds from flooding (see next section).

48.7.2 Flooding of Wastewater Treatment Plants

In gravity sewer systems, wastewater treatment plants are usually located at the downstream end of the system. Often the only suitable location may be on flood-prone land.

Flooding of a treatment plant or oxidation pond is very undesirable because floodwaters will entrain pollutants from the treatment units or ponds and wash them downstream. Recommended actions are either:

- locate the plant or pond above flood level, if the site permits, or
- enclose the plant or pond with a raised wall or berm to keep out floodwaters.

It is recognised that land constraints are a serious factor with many wastewater treatment plants. A reasonable compromise is to locate the most highly polluted parts of the treatment process, the inlet, primary and secondary treatment stages, above flood level or within berms. Tertiary polishing ponds, which require large land areas, may be located on the floodplain as they have only a low concentration of pollutants and the consequences of flooding and wash-out are less severe.