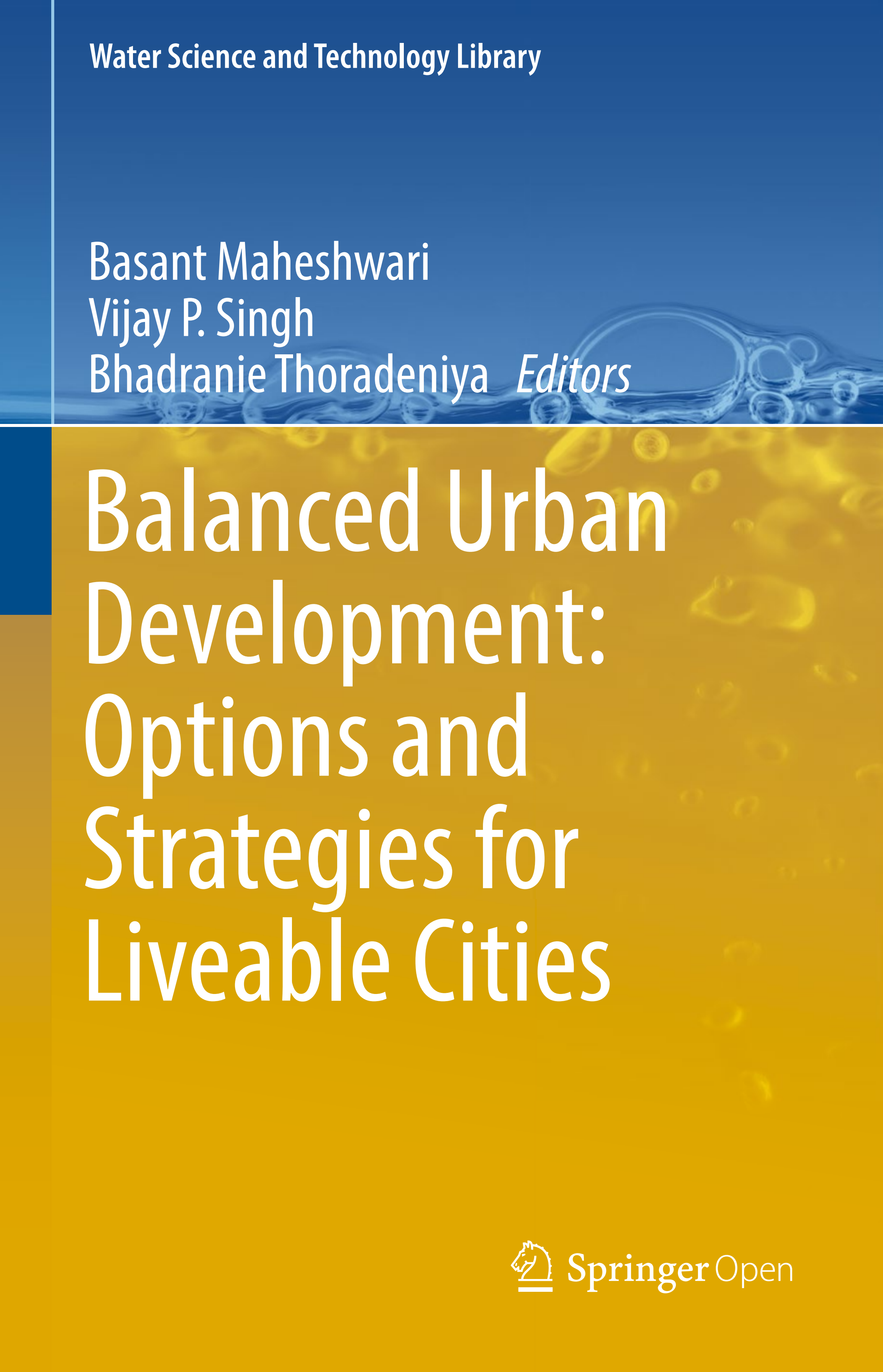

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MISTRA URBAN FUTURES

WESTERN SYDNEY UNIVERSITY

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Chapter 6
Decontamination of Urban Run-Off: Importance and Methods

Leo Crasti

Abstract The removal of contaminants from urban run-off waters is vital to preserving the health of urban communities that live in contact with and around the receiving waters. The apparatus developed is a Stormwater Screening and Filtration Unit (SSFU), which embodies a series of processes for the removal and retention of trash and litter, sediment, suspended solids, emulsified hydrocarbons, dissolved nutrients (both Total Nitrogen and Total Phosphorus), heavy metals and other chemicals as required by the run-off water composition and the receiving water quality of a specific catchment.

In addition to a small foot print and negligible installation time, the implementation of an SSFU as the sole method of contaminant removal from runoff, can reduce capital expenditure often by more than 60 % and reduce on-going service cost by over 80 %, when compared to the implementation of conventional multiple treatment measures in a treatment train as a means of meeting pollution reduce targets.

The SSFU is available to integrate with various applications, ranging from in-line drainage lines, as a pre-process within on-site detention (OSD), discharge outlets to wetlands or receiving waters and with the addition of passive secondary media can remove even fine silts and chemicals prior to harvesting and aquifer re-charge.

Keywords On-site detention • Stormwater screening • Filtration • Runoff • Wetlands • Contaminants

6.1 Introduction

Contaminants in stormwater runoff are a key contributor to the collapse of freshwater ecosystems and at source measures need to be implemented to address water quality issues (Allison et al. 2008). The findings cite reluctance by authorities to

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mandate Water Sensitive Urban Design (WSUD) treatment measures as the additional capital and maintenance costs may inhibit acceptance and implementation.

Our investigation amongst engineers, property developers and builders shows the reluctance to implementation is primarily driven by costs associated with loss of land use, installation and maintenance. Our research and development aims were to provide a low impact, low cost easy to maintain solution for the removal of all contaminants that are undesirable to receiving waters. The benefit generated by achieving this outcome in addition to preserving the environment and human health, is allowing the water to be safely used for recreation, agriculture and harvested for re-use.

To further bring the importance of preserving freshwater quality into focus the fundamental importance of fresh water as a limited resource needs to be stated. Water (H_20) on our planet earth is finite, with astronomers agreeing that water was imported to the planet by ice meteors. Abramovitz (1996) estimates that the human use of fresh water has increased 40-fold in 300 years with 50 % of that increase since 1950. Lefort (1996) calculate that only 0.01 % of the world's water is available for regular human use.

6.1.1 History of Stormwater Management in Australia

Australia and the cities of Sydney, Melbourne and Brisbane are amongst the most recently developed urban environments in the western world. Urban design was greatly influenced by the original British colonists and further impacted by European migrant designers. Because of this recent history, there are substantial lessons that can be learnt by reviewing this history.

There have been a number of articles published that draw from archaeological records that clearly show a relationship between urbanisation and pollution of creeks, rivers and harbours (Everingham 2007). The migration in the mid-nineteenth century brought debris, garbage and deterioration of harbours. Roadways became drains and the source of sediment erosion, whilst also transporting animal manure, industrial discharge and sewage that flowed into natural waterways (Fraser 1989). Yielding to public pressure caused municipal and other public authorities to adopt urban drainage systems (O'Loughlin and Joliffe 1987). Prior to the 1890s, urban drainage included both sewer and stormwater systems. Stormwater in time was seen as a problem, causing flooding and disruption to the drainage system and surrounding infrastructure.

Separate stormwater and sewer systems became an Australian standard practice by the 1920s (O'Loughlin and Robinson 1999) as a response to public concern of waterborne diseases. From this point on, sewer systems were well designed and implemented, whilst stormwater drains became a mechanism to transport street and surrounding waste to receiving waters. This followed a similar trend in Europe and the US. Unseen below ground and unnoticed because of dilution, the practice has continued unabated until recent times.

Though the removal of visible gross pollutants has been a focus through the implementation of trash racks and GPT's, a large amount of anthropogenic contaminants continue to enter the waterways. Allison et al. (2002) note the Australian Federal Government Senate enquiry into Australia's Urban water management, which noted that many of Australia's waterways are in critical condition due to pollution. Studies and experience by (Pratten 2009) and (Allison et al. 1998) showed that 90 % of gross pollutants entering both Sydney Harbour and Melbourne's Port Phillip Bay sink to the bottom and give the deceptive appearance of clean water.

More recently, the Sydney Institute of Marine Science (SIMS) have been engaged to conduct detailed studies of the sediment beds in Sydney Harbour. Their success has spread to a global linkage titled "World Harbour Project" aimed at addressing the challenges of urbanisation and the impact on marine environments. Recent achievements by SIMS includes the confirmation that micro plastics have entered the food chain and are compromising the population and health of benthic organisms in the sediment beds. Further studies are in progress to quantify the impact of heavy metals and numerous other chemicals transported by stormwater, on the marine eco system. These studies are also parallel by the CSIRO in Australia and linked groups worldwide.

There are numerous references that express concerns with the accumulation of a diverse range of contaminants in aquatic sediment beds. The author proposes that all urban designers should adopt a proactive approach and limit if not eliminate all anthropogenic derived content from runoff water and thereby not be party to increasing the current environmental degradation and threats to bio diversity.

6.2 Urban Drainage Design

As cities developed over the centuries, drainage systems were installed underground. Though this served to create an improved built environment, the result was a hidden disposal system which transports matter into waterways and in turn seas and oceans. A dramatic example is the Pacific Gyre and the impact of micro plastics spreading across all coastlines.

In recent times the principles of WSUD have been promoted to urban designers. The Australian Runoff Quality (ARQ) 2006 was used as a core document and source of design parameters. Installing and operating the SSFU in both existing drainage networks as well as an integrated element of WSUD was a primary design goal. Variants were developed for application in locations such as:

- In-line as an integral part of the drainage line, either a new or existing pipeline or culvert.
- Off line in circumstances where an in-line application is not practical. However the method of diversion or flow splitting requires specific design knowledge to avoid hydraulic jumps and premature by-pass
- End of line at headwalls which favours existing drainage outlets

Table 6.1 Contaminant type with specified percentage and design reduction targets

Contaminant/pollutant	% Reduction target	% Reduction possible
Trash and litter (gross pollutant)	90 %	95 %
Total Suspended Solids (TSS)	85 %	90 %
Total Phosphorus (TP)	65 %	80 %
Total Nitrogen (TN)	45 %	70 %
Hydrocarbons, including emulsified and free	90 %	90 %
Heavy metals		90 %
Turbidity		50 %

- Prior to detention systems, ensuring water entering a detention basin or tank is free of contaminants allowing the OSD to perform it's function without maintenance.

6.2.1 Contaminant Type and Load

The following are a list of contaminants that are considered to occur in drainage systems. The highlighted contaminants are typically noted in environmental policy documents with percentage reduction targets (Refer Table 6.1)

Gross Pollutants These include trash, packaging, organic matter such as a leaf litter and grass clippings, clog drains and choke waterways. Though trash, particularly plastics are obvious pollutants, some question whether leaf litter and grass clippings are pollutants or contaminants. The simplest way to determine if a substance is a pollutant (or contaminant) is to relate the substance and it's influent volume to the pre-urban condition of that catchment. For example, litter fell from trees and provided a compost bed below the tree canopy providing a microenvironment, for a diversity of organisms. The compost bed was reasonably well anchored and acted as an energy dissipater even during intense rainfall events, allowing water to filter into the soil or migrate at low velocity to the nearest water course. However in an urban landscape, litter falls and is either not encouraged for aesthetic reasons and removed or accumulates on an impervious surface and is washed away at high velocity during the next (often mild) rainfall event. This large volume of raw litter overloads the downstream water way and can have significant detrimental impacts, including turbidity increase, coverage that excludes light, delivery of nutrient overdose and subsequent oxygen depletion. Additionally that raw litter may be foreign to the environment and not able to be digested by the indigenous organisms.

Sediments Sediments washed from impervious surfaces (roof surfaces, pavements etc) or as erosion can change the light penetration into water, clog the gills of fish and negatively impact their breeding and feeding habits. Particles (dust and dirt) generated from road surfaces (Dempsey et al. 1993) carry a range of contaminants

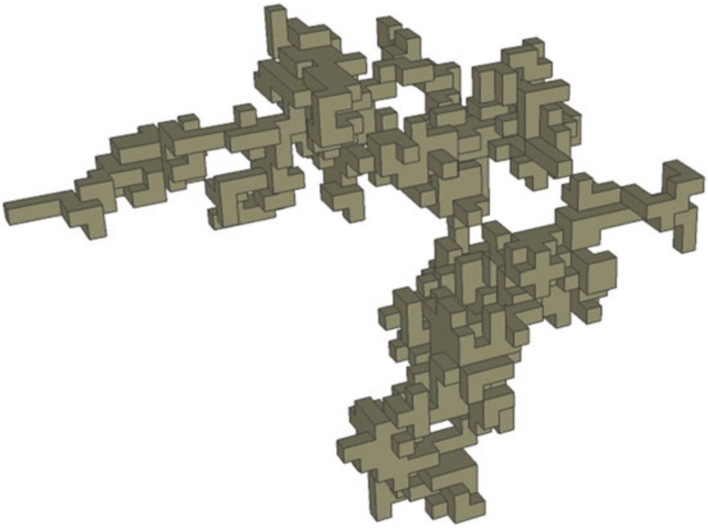


Fig. 6.1 40 μm particle illustration shows large surface area and high chemical entrapment capability

and heavy metals. The author has worked with Sydney and the University of Western Sydney to understand the role of particles as a transport mechanism. Figure 6.1 shows a an illustration of a 40 μm particle which was created from actual video recordings then translated into a 3D animation medium. This clearly shows that the particle comprises a flocculation of sub particles, creating a combined capacity to attract chemicals, both by way of surface attraction over the large surface area, as well as mechanical entrapment between the sub particles. There is further evidence emerging (which is the subject from the current studies) that these particles conglomerate to form sediment and retain the chemicals for extended periods of time. Of further interest is that nutrients such as Nitrogen have an affinity for particles. Analysis of pond systems showed that only 10 % of the total Nitrogen was available in solution whilst the remainder (90 %) was attached to particles. This view is further supported by the addition of clay to water in order to extract nutrients and improve water quality (Bakel 2006; Guo et al. 2011). There is further evidence in support from student studies and field experiments that correlate nutrient release time to catchment materials, which show that the capture of particles is an effective method of reducing nutrient load in run-off as the wetted exposure time to effect release is longer than the duration of run-off from a local catchment, prior to entry into infrastructure drainage systems. This is the subject of current research.

Organics These are mostly chemical compounds used in the manufacturing of consumer products, which, at even low concentrations have serious health implications. Analysis of stormwater (Pitt et al. 1995) showed that a significant portion of stormwater run-off contained extreme to moderate toxic organic compounds and that filtering of particles to 40 μm reduced toxicants by 70 %.

Nutrients When added to an aquatic environment can quickly cause excessive algae growth consuming available (dissolved) oxygen previously available for other aquatic flora and fauna. Then as algae die, decomposition further reduces available oxygen, which can only be replenished by a significant change to the water body, such as aeration or a complete water change. Isolated water bodies can suffer long-term loss of bio-diversity if the condition is allowed to continue. This is known as eutrophication and is harmful to fish and other aquatic organisms. Certain strains of algae are sufficiently toxic to be harmful to livestock and humans.

Oil and Grease These in stormwater introduce toxicants and coat plants and the gills of fish with a film preventing the exchange of oxygen and nutrients. Some of these compounds are dangerous even at low concentrations, include Chlorobenzenes and Surfactants, which as a generic group, impact on the health and population of benthic organisms.

Heavy Metals These are transported by urban run-off mostly bonded to particles as noted earlier. These are of concern due to their potential toxicity and ability to bio-accumulate. There is also growing evidence that these heavy metals are finding their way into the food chain, with many harbour based fisheries being closed. The Food and Agriculture Organisation of the United Nations have noted in part that many harbours world wide are adversely impacted by the heavy metals (Sciorintino and Ravikumar 1999).

Chlorine, Acid Wash and Erosion from the maintenance of pools, spas, and fountains can pose a major risk to stormwater through erosion, increase in sediments and the addition of pollutants such as chlorine and acid wash.

Bacteria and viruses are pathogens present in faecal matter which can be present in stormwater runoff as pet and wildlife waste, leaky septic systems, runoff from agriculture, broken sanitary sewers, and cross connections.

Thermal stress occurs when warmer stormwater runoff enters a coldwater system negatively impacting on cold-water dependant species.

Improperly designed and/or maintained stormwater infrastructure offers habitat for rodents, small animals and other disease carriers.

6.2.2 Treated Flow

Experience and simple observation shows that after a period of rainfall, a catchment “cleans-up”. Motor vehicle drivers are well aware of the slippery road phenomena for the initial period of rainfall on roadways.

Therefore, it stands to reason that only a portion of the rainfall event needs to be treated. This is defined as the treated or design flow and is a fundamentally critical design assessment, which needs to be made prior to selecting a treatment measure.

6.2.3 Definition

The gross flow is the total flow, which may potentially be conveyed by the drainage system and is typically determined by local area needs and is expressed as a flood event, determined from statistical records. The treated flow and gross flow are not necessarily interrelated. For example a drainage system sized to accommodate a 1 in 100 year flood event will be larger than if designed to accommodate a 1 in 25 year event. The defined gross flow alters the size of a pipe or channel without necessarily altering the treated flow, which is required to pass through a process to substantially remove the target contaminants.

There is a misunderstanding that a 3 month rainfall event (being estimated as approximately 50 % of a 1 year event) is sufficient as the treated flow. The Australian Runoff Quality Guidelines (Engineers Australia 2006) notes that a 3 month event should mobilise up to 90 % of the contaminants in a catchment. This level of treated flow is simplistic and could lead to under design and inadequate performance. The following additional factors need to be included in defining the treated flow.

Firstly, the nature of the catchment and the extent of impervious areas creating high or low velocity flows needs to be considered. This will have a bearing on the flushing effect. For example, smooth hard surfaces at higher gradients will mobilise contaminants at a lesser water volume than rough low gradient surfaces.

Secondly, is the flow and time delay within the catchment area. Many drainage systems exceed 200 m in run length, with pipe flow velocities of 0.5–2.0 m/s. When overland flow times are added, the catchment time lag between entry points close to a treatment measure versus the furthest catchment areas could exceed 10 min.

If a 3 month event equivalent flow were treated, then only a small portion of the catchment load will be included in the treated flow and potentially a majority of the load would by-pass the treatment measure. Off-line systems predominantly suffer from this misunderstanding.

Therefore, the treated flow definition in sizing a Stormwater Treatment Measure (STM) is to firstly use the 3 month event as a minimum, then add the catchment area time delay factor to determine the actual treated flow and link this with the rainfall event hydrograph.

In general terms, a one (1) year event typically represents the minimum treated flow with increased treated flow up to a five (5) year event in catchments with extended flow paths.

The application of “First Flush” principles based on a one (1) factor design parameter of for example a 3 month ARI is flawed. The aim of this section is to propose a treated (design) flow calculation, which is consistent with all the research results over a 20 year period and recommends that designers take into account the nature of catchments and the sensitivity of receiving waters on a case by case basis.

6.2.4 The First Flush

Jean et al. (1997)) analysed 197 rainfall events in 12 separate catchments in France and Germany. Their analysis included the creation of non dimensional models and charts know as M(*V*) curves (Refer Fig. 6.2) which related flow rates and concentrations versus cumulative flows and mass transported, for a variety of contaminant types. This is a comprehensive and thorough attempt to establish a "first flush rule" which could be used to establish a treated flow ratio and hence size a treatment measure. Comment and analysis was also provided for several earlier attempts by various authorities and experts to create a first flush definition and 29 references were also included. Typically these attempts were proposing a rainfall volume % versus pollutant transport volume %. The authors chose to use 30/80 ie 30 % of the rainfall volume would transport 80 % of the pollutant load from a catchment as the definition of the "first flush".

The conclusion reached was unexpected. In the conclusion to the paper the authors wrote, "*The analysis of the data available in France and abroad shows that this 30/80 first flush is very rare*." This was stated in the context that the ratio was too low and that a much higher rainfall volume had to be treated in order to capture a high proportion of pollutants. The conclusion in the paper then went on to state, "*Nevertheless, it appears that **the concept of the first flush can not be used alone** to establish a reliable design methodology for treatment facilities, as it does not take into account the complexity and variability of the phenomena involved. It is consequently proposed to renounce the first flush concept itself*".

6.2.5 Sediment and Pollutant Load Modelling

Rodriguez et al. (2010)) recognised that modelling methods, which reliably predict the relationship between flow and pollutant transport from a catchment area, are becoming a necessary requirement in urban drainage design. Of note is the constant reference to complexity and time lag. The issue of complexity acknowledges that input data and parameters in the simulation need to be varied across catchments, drawing the conclusion that there are no simple underlying constants. The time lag factor is a common denominator in all studies reviewed, which clearly shows that sediments will continue to be transported and appear in the flow path well after the rainfall peak has passed.

The conclusion drawn from these and several other papers is that a simple across the board rule cannot be applied and that intra-catchment time lag must be a primary function within the calculation.

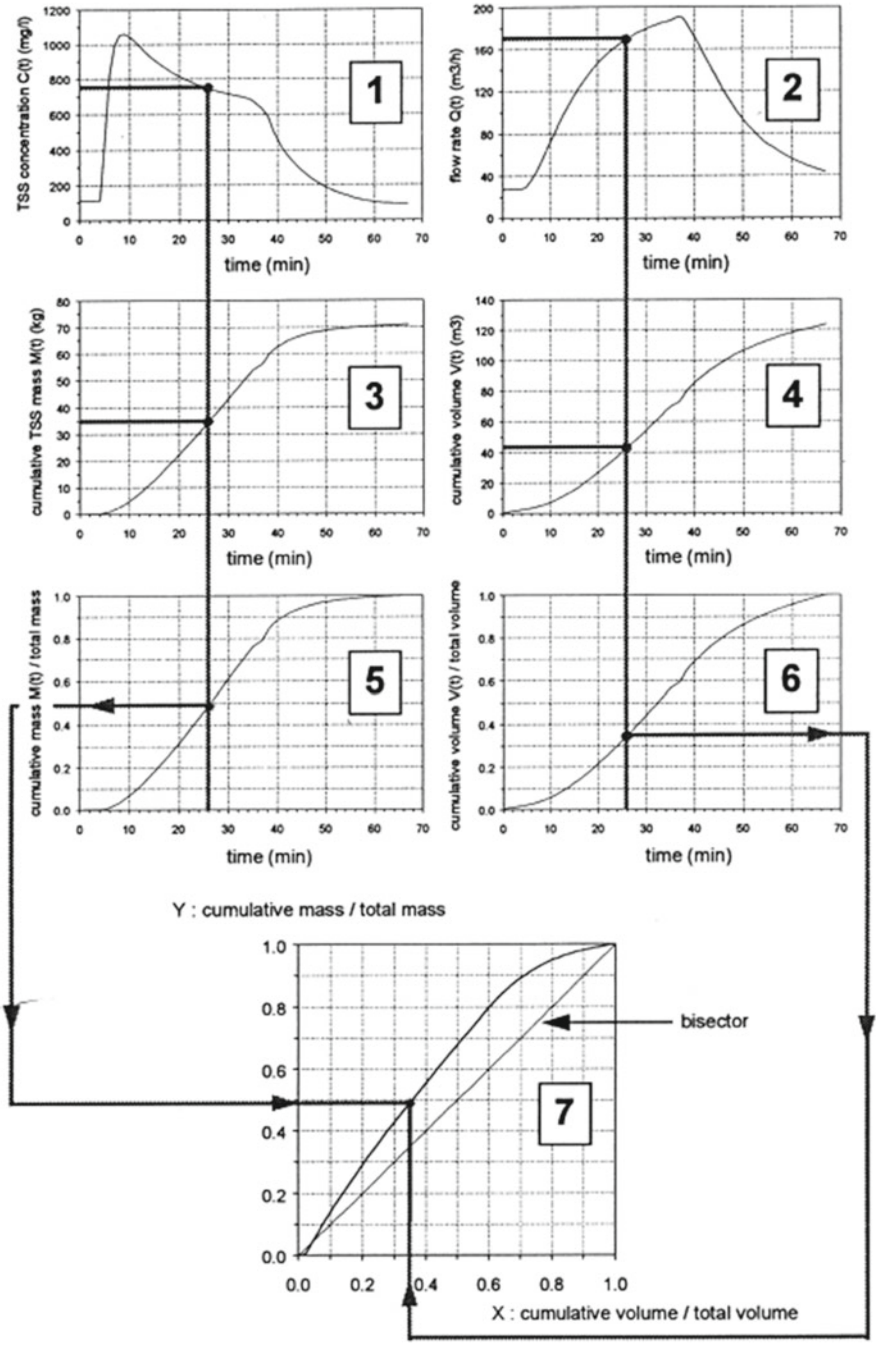


Fig. 6.2 Example of M(V) *curve* for TSS

6.2.6 *The Australian Runoff Quality Guideline 2006 (ARQ)*

The ARQ is a comprehensive document, which intends to provide a design guide toward the application of WSUD. Of note the ARQ makes the following comments. Section 2.4.2, notes that 70–90 % of pollutants are exported by storm events of 1 year ARI or smaller. Particle sizes down to 20 μm size range are the prime carriers of toxic contaminants and nutrients (Refer Fig. 2.1 in Engineers Australia 2006).

Chapter 8 in Engineers Australia (2006), Melbourne Water is referenced as expecting a 70 % reduction in litter load to 20 mm in size, by treating flows equivalent to a 3 month average recurring interval (ARI). A further acknowledgement follows that treating a one (I) year ARI would be necessary for the removal of particles to 90 %.

6.2.7 *The Catchment Hydrology*

The hydrology of a catchment created by man-made development will exhibit similar characteristics to any watershed (catchment). Principally, that rainfall impacts on the surface and transfers energy to mobilise particles, then as water depth increases, water starts to flow at a velocity determined by gradient, then enters a drainage system, which conveys that water to a discharge point. Water becomes the carrier of contaminants.

The Fig. 6.3 shows charts of the relationship between various factors that impact on water flow in a typical watershed. The same factors also apply to a man made catchment where natural flow paths are replaced by a drainage system.

The factors, which influence treated flow are:

1. **Flow gradient** in the catchment being the gradient of areas water must flow over before entering a drainage conduit. Flat areas will hold more contaminants and require higher flow rates than larger gradients to mobilise materials.
2. **Impervious areas** are often simplistically the only area considered as the catchment, however run-off from other areas both pervious and semi pervious also hold contaminants and may take greater flows to mobilise these materials. A typical example is soil and organic matter, which is the source of nutrients and other chemicals, held in landscaping surrounded by paved areas. Soil types and the moisture levels will also generate different flow conditions and materials export characteristics.
3. The **texture of catchment** areas will also influence the flow rate required to mobilise contaminants. Smooth concrete surfaces will have a lower flow versus contaminant transport rate than course surfaces such as bitumised pavements, which inherently hold sediment.
4. The **flow gradient of drainage** conduits will induce large differences in flow velocity, which is the fundamental source of energy that transports material. Gradients generally range from 0.5 to 3 % and induce flow velocities of 1–5 m/s

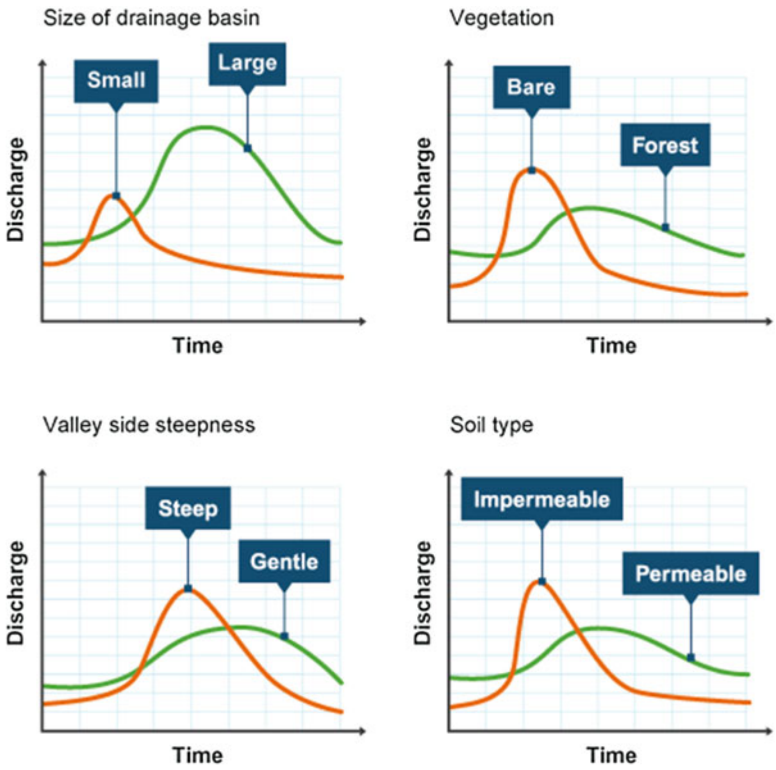


Fig. 6.3 Shows charts of the relationship between catchment factors and discharge/time relationship

when fully charged. However as Figs. 6.4, 6.5, and 6.6 show there is a non-linear relationship between flow depth, rate and velocity. At low flows, drainage lines and pits accumulate a range of contaminants. This is exacerbated by the need to often design drainage systems for extended events such as 1 in 50 and 100 year flood events as overland flow paths may not be available without asset damage. Large sized pipe systems cause shallow flow depths and low mobilisation flows, which further add to the accumulation of materials within the drainage system. The relationship between pipe size, gradient and the likelihood of materials ingress into the drainage system are all factors, which need to be considered in the level of treated flow and operation of an STM.

5. Materials within the catchment are transported relative to their **physical properties**, such as buoyancy, density, shape and size. There are further more complex factors such as wetting and clumping which complicate attempts to synthesise and model contaminant behaviour. Practical observations of many urban drainage systems reveal that accumulated materials are left behind by low rainfall events as these materials are dry and are retained by rough surfaces, then as follow on rainfall occurs, these clumps of material are carried into drainage inlets.

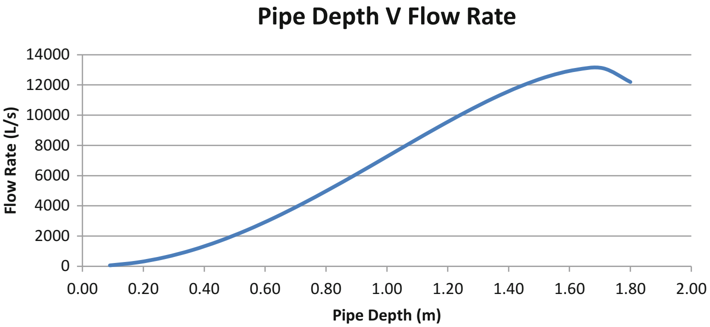


Fig. 6.4 Flow rate increases 300 % from 3 month to 1 year ARI flows

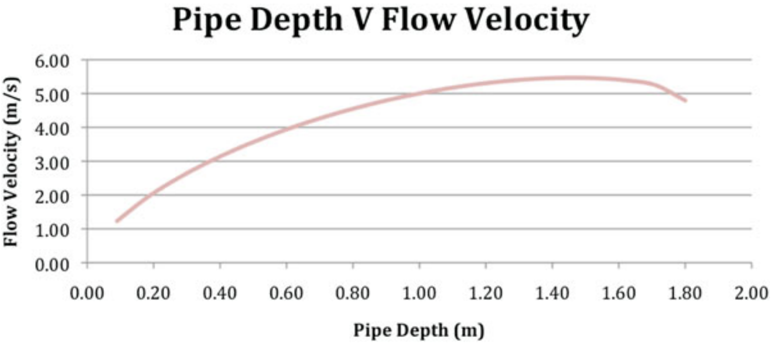


Fig. 6.5 Flow velocity increase of 200 % from 3 month to 1 year ARI flows

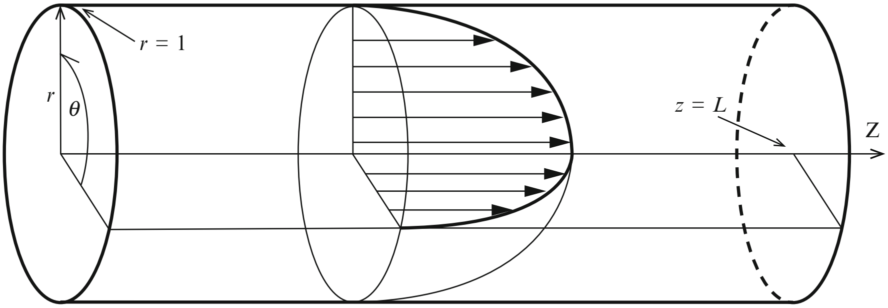


Fig. 6.6 Differential velocity profile

6.3 Proposed Design Flow Calculation

There is sufficient literature to indicate that a one (1) year ARI is the minimum rainfall event that will most likely mobilise a high percentage of the contaminants within a catchment. Therefore this should be assumed as the base design flow, or minimum treated flow.

In addition, consideration is required for the time lag factor across the catchment. This will vary depending on the catchment characteristics and influencing factors listed earlier, which influence the behaviour of water as a transport medium. There are a number of modelling tools, which allow designers to calculate the time lag of flow across surfaces and in drains. Tools that relate pollutants and the interaction with water are still in development and are unlikely to be widely used until catchment specific data is accumulated and categorised/classified.

The aim of the design is to ensure that the **entire** catchment surface, (which may collect contaminants) is exposed to a rainfall equivalent to a 1 year ARI with sufficient time for that flow to arrive at the STM, before by-pass occurs. By definition therefore, the level of flow to be treated in many instances will be higher than the minimum 1 year event, and will vary in accordance the rain fall hydrograph for that area.

6.4 Location of a Treatment Measure

Urbanisation and man-made catchments typically involve an increase in impervious areas and a change of gradient. Unfortunately, the net result is a significant increase in discharge volume over the same time interval. The location of an SSFU will vary with each catchment area topography and access to discharge or receiving waters.

It does not necessarily follow that the least number of SSFU's installed will be the lowest cost alternative. Aggregating pipe flows to convey water to one discharge location and hence one SSFU will invariably increase the cost of the drainage system. Whilst potentially reducing the cost of the SSFU the net result may a total capital increase, which could have been avoided by reducing pipe work and increasing the number of SSFU's. Other factors are long term service and maintenance, which may be, favour one centralised SSFU due to easy of access.

A common practice is to location of an STM after an OSD as the flow is low and the STM is down sized, resulting in an apparent lower capital cost. This includes the OSD as the primary treatment measure with significant consequences. Firstly any limited screening ahead of the discharge orifice will be blocked causing the OSD to over flow, releasing the buoyant materials. In some cases the overflow relief weir may also become blocked, back up the drainage system and cause inundation with asset loss. A final consequence is that the OSD become part of regular maintenance requiring intensive labour activities often in a confined space and subject to occupational health and safety provisions. Ultimately, this inadequacy will need to be solved driven by both environmental non-compliance and on going costs (Figs. 6.7, 6.8 and 6.9) shows an example of an SSFU, designed by the author.

Figures 6.10, 6.11, and 6.12 show some examples of on-site detention pits and tanks, which were not fitted with pre-treatment measures. Typically screens are blocked and high water level untreated discharge occurred in even moderate rainfall events as a result of blocked orifice plates.

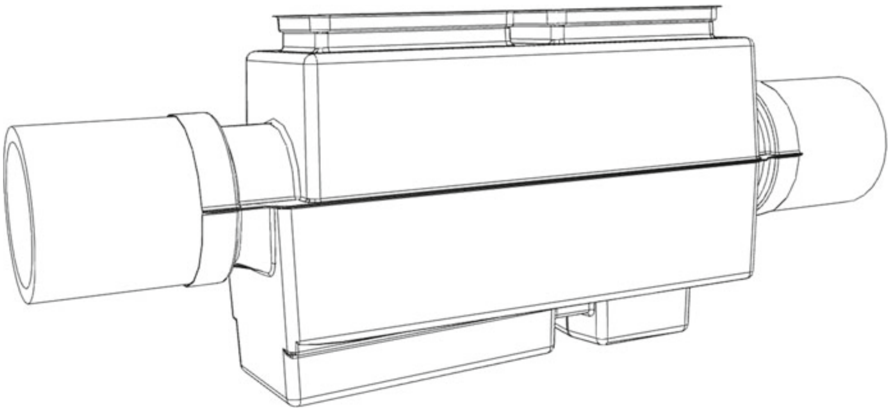


Fig. 6.7 Chamber including transition and processing cartridge housing

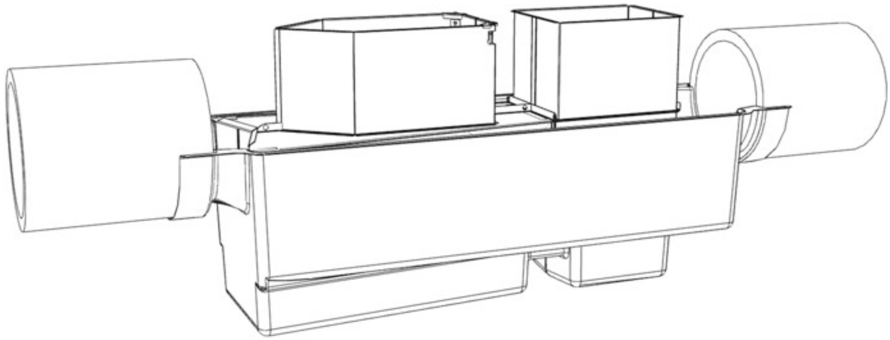


Fig. 6.8 Chamber *upper* removed exposing processing cartridge

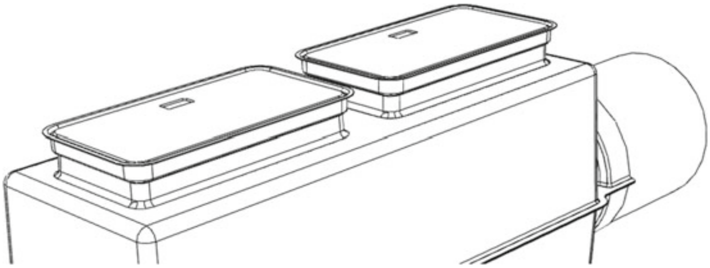


Fig. 6.9 Access available through lockable covers

There are two distinct OSD pre-treatment solutions. One is to install an SSFU in the pipe work prior to the OSD. The alternate is to integrate the SSFU processing cartridge into the OSD construction. The latter in most cases is the lower cost solution. If an open wetland is to be used as an OSD then pre-treatment is recommended (as discussed in the following section) with the addition of an overflow riser to prevent buoyant materials from being discharge during extreme rainfall events.

Fig. 6.10 This picture shows mesh screen in an open *top* detention pit, preventing flow through the orifice plate

Fig. 6.11 This picture shows mesh screen in an underground detention tank fully blocked, preventing design discharge

Fig. 6.12 This picture shows a mesh screen, which is unsecured to the walls of an underground detention tank with some of the trash collected whilst smaller materials were allowed to be released

Open detention basins can then become part of the site amenity as a permanent water feature, with a flow metering weir and allowance for a top water level increase during flood events. Restricted to flood mitigation and not a treatment measure, the open basin (pond) can be used to restore bio-diversity as an integral point of the development and avoid costly remediation required by a build-up of sediments, trash and litter.

6.5 Wetlands, Natural and Constructed

Both natural and constructed wetlands either fresh or saline are a transition between land and water and may hold surface water on a permanent or periodical basis. Some wetlands are basins that are designed to hold water whilst others may be designed to allow full or partial infiltration and may not be permanent water bodies. All forms of wetlands have a role in water quality improvement as well as being of environmental and social benefit.

In all configurations wetlands can deteriorate and are subject to collapse due to influents generated by urbanisation. Though litter traps may provide a partial solution for visible pollutants, the main cause of collapse is from the adverse impact of nutrients, silt and toxic substances many of which also include heavy metals.

The conclusion that can be drawn is that wetlands should not be used as a dumping ground for urban run-off with an expectation of self remediation. Wetlands should be regarded as a sensitive environment, which needs to be protected from the discharge of contaminants derived from urbanisation.

Avian botulism in pond birds is commonly reported in circumstances where there is a low oxygen content in the water. The botulism bacteria are common in many soils and thrive as oxygen levels deplete. Maggots also concentrate the toxins.

The cause of an anoxic condition or eutrophication (depletion of dissolved oxygen) is well documented. This often occurs when the rate of oxidation of organic matter by bacteria is greater than the supply of dissolved oxygen. Eutrophication is often caused by the inflow of phosphates present in detergents, fertilizers or sewage. These conditions are manifested by "algal blooms" visible as green slim in or on the water surface.

In conclusion, water entering wetlands should be of a similar quality to that which would have occurred before urbanisation. This therefore requires influent flows to be removed of harmful contaminants.

6.6 Broad Spectrum Treatment

The SSFU is designed and tested to remove a broad range of contaminants from the catchment run-off. Table 6.1 shows pollutant reductions expressed as a percentage for a range of contaminant groups. The table shows the generally required reduction targets as required by many authorities, alongside the potential reduction achievable if the SSFU is installed and serviced in accordance with best practice and preferably by a trained technician.

To achieve the full potential reduction performance, the design (treated) flow must be well defined so that contaminated run-off is treated and that the SSFU is located to take full advantage of the processes included within the SSFU.

In addition to the SSFU design performance, a managed inspection and service routine is required to ensure that captured materials are removed before these compromise the performance of the processes with the unit.

For critical applications where receiving waters are deemed sensitive, additional telemetry measures are available on request. These measures include water quality monitoring, performance logging and remote data transmission. These measures are custom designed to suite the specific needs of the local environment.

In summary a correctly specified, installed and serviced SSFU nominally returns run-off water quality to pre-urbanisation standards.

6.7 Design Performance

The development of the processes started with defining the contaminants, required to be removed by local environmental policy. It is noted that the current method of defining compliance is to publish a table of contaminants and then specify the reduction target as a percentage reduction (Refer Table 6.1). It is our view that absolute water quality targets consistent with the nature of receiving waters should be adopted. Basing discharge water quality on percentage reductions has the potential for under and over performance by STM's. Of greater potential, is that the performance of treatment devices is subject to misinterpretation. As an example the definition of suspended solids is not consistent and is also overshadowed by the term totally suspended solid (TSS), which can include particle sizes from 2.0 mm down to 8 µm for very fine silt. GPT's generally claim removal of suspended solids, however theses solids also have specific gravity greater than 2, which by definition is will not be suspended, unless in high flow turbid conditions. It also follows that materials of this density are sands and not associated with the attraction and transfer of chemicals.

Dempsey et al. (1993) found that the concentrations of heavy metals and total phosphorous (TP) were highest in particles between 250 and 74 µm in size. Walker and Wong (1999) compiled particle size grading from numerous catchments and charted that 20 % of particles by mass could be below 100 µm in size. The conclusion reached in determining the sediment removal aims was that particles as small as 20 µm need to be removed. This conclusion is supported by (ARQ) who observed that suspended solids in urban run-off typically occurs in the 1–50 µm size range.

Physical and chemical properties of contaminant groups were analysed to establish the removal process and retention mechanisms.

Table 6.1 shows a summary of the reduction targets currently adopted by Environmental and Local Government Authorities and the potential SSFU reduction levels which were established during performance testing and field sampling.

6.8 Process Design

The design and development of the processes included in the SSFU followed a series of disciplined steps that are briefly described in this section. The disclosure of further details are available to interested parties, but may be the subject to confidentiality as some of the process details are the subject of patent applications and on going research.

The first critical element in the design was an understanding of the relationship between catchment, contaminants, rainfall and water flow. This was described earlier as the treated (design) flow and establishes influent characteristics that must be dealt with in the design and operation of the SSFU.

In conjunction with treated flow the mobilisation of materials and the relationship between pipe depth, flow and velocity (Fig. 6.6) was studied and simulated. Contaminants of varying sizes and densities were tested to understand the mobilisation forces and reaction to flow patterns. After analysis, flow modelling and testing an in-line diversion was adopted as the most reliable orientation of the SSFU relative to the flow. Off-line diversion efficiency was sensitive to pipe gradient, flow velocities, weir shape and attack angles, therefore should only be used as a last resort.

During hydraulic modelling differential velocities across a pipe section (Fig. 6.6) generated unwanted turbulence within a receiving chamber. A transition was developed (Fig. 6.7), which reduced the differential velocity across the pipe section and eliminated turbulence, creating near laminar flow within the chamber. In-chamber velocities and flow patterns were also analysed and modelled to establish a self cleaning action at near zero differential cross screen pressure, eliminating the tendency for materials to adhere to screen surfaces. This modelling also included relating the in-chamber water flow factors to screen materials, orientation and types.

Trash and Litter design reduction was set at 100 %, on the basis that this group is generally buoyant and the blend of litter and packaging could not be separated. A buoyant materials chamber is provided which is one-way entry, which together with the modified flow patterns eliminates the possibility of draw back and re-mobilisation in circumstances where discharge maybe temporarily below water as in a tidal or detention application (Fig. 6.8).

Total Suspended Solids (TSS) design reduction was set at 90 % to reflect the understanding that particles are the prime carriers of nutrients, heavy metals and some hydrocarbons. Figure 6.1 is an illustration of a particle, which is approximately 40 μm in size. The particle appears as a flocculation of micro-particles, which creates a large surface area and extensive opportunity for chemical entrapment (as described earlier).

Background levels of Nitrogen are essential for ecosystem biota at certain concentrations. As a general rule, it is the level of nitrogen in the environment that limits plant growth in fresh water (Engineers Australia 2006), and therefore if concentrations are too low there may not be enough biological material to sustain the ecosystem. This nitrogen can enter waterways as nitrate, nitrite and ammonia, which are taken up within the aquatic community to maintain life. Nitrogen is a major component of proteins, hormones, chlorophyll, vitamins and enzymes essential for plant life, predominately in the production of plant and animal tissue.

This means that when decontaminating stormwater there must be some level of nitrogen that remains post treatment. The Australian Runoff Quality Guidelines (Engineers Australia 2006) cites a concentration of approximately 0.8 mg/L for land use classified as ‘Forest’, which would most likely represent pre-anthropogenic conditions, whereas research of untreated urban stormwater is recorded as 3.09 mg/L and therefore a reduction of up to 70 % may be required to return water to background concentrations.

Total Nitrogen (TN) design reduction was set at 70 % on the above basis and further supported by numerous papers that together with our own research, alerts that TN in urban run-off has been recorded up to several times greater than the N necessary for biological sustenance in receiving aquatic environments. In peri-urban areas most of the N, which impacts on receiving waters is bonded to particles from fertilizers, wastewater and many other products.

To accomplish the reduction particle sizes to below 20 μm are removed by the combined action of screening and if necessary tertiary media. Nutrients promote growth of aquatic plant life including floating macrophytes and in large concentrations produce algal blooms on the surface. With an increase in nutrients, algal growth becomes excessive often resulting in the production of toxins (refer comments earlier).

Total Phosphorus (TP) design reduction was set at 80 % on the basis that P in water is a trigger for alga in freshwater. P compounds are slow to dissolve and therefore many accumulate in sediment. Furthermore, the availability of P in the pre-urban environment is low and released from mineral bonded conditions. Removal of TSS also removes the soil bonded P allowing low levels of dissolved background P to remain.

Hydrocarbons in run-off water have many adverse impacts on receiving waters due to the extent and complex nature of additives. Reduction was set at 90 %. They appear as a scum, are emulsified and also bonded to particles. The method developed is to coalesce micro-globules that attract into larger globules, and then apply a range of capture methods to suit the nature of the catchment area. In low hydrocarbon concentration catchments, such as residential developments a hydrophobic media is utilised. Whereas for potentially high hydrocarbon concentrations such as infrastructure applications a non-return separation process has been developed which can be monitored and purged at a higher frequency than the main service interval. If hydrocarbon spills are a potential, then a dry sump to act as a bund can also be introduced.

Heavy metals are included in the target contaminants and are removed by virtue of their attachment to TSS. Reduction was set at 50 % and testing indications higher removal rates are achievable.

Turbidity is also reduced by a large reduction of TSS. In sensitive receiving water conditions an additional tertiary media is added to boost reduction by a further 50 %.

All of these processes are housed in a processing cartridge (Fig. 6.8).

6.9 The Final Device

The apparatus developed is termed a Stormwater Screening and Filtration Unit (SSFU).

The following design features are included in the SSFU in addition to the contaminant removal design targets noted earlier. The SSFU construction is compact and light weight. Installation is by on-site equipment and can be installed as part of a new drainage installation or retrofitted. Pipe adaptors are provided for varying pipes sizes. Variable risers are provided to match inverts. Inspection and service covers (Fig. 6.9) are light weight and lockable. Servicing intervals are calculated on the basis of catchment area load with nominal service intervals of at least 12 months.

Catchment loads vary with catchment nature and type. Process and containment recommendations are provided to designers to optimise water quality, installation and service costs.

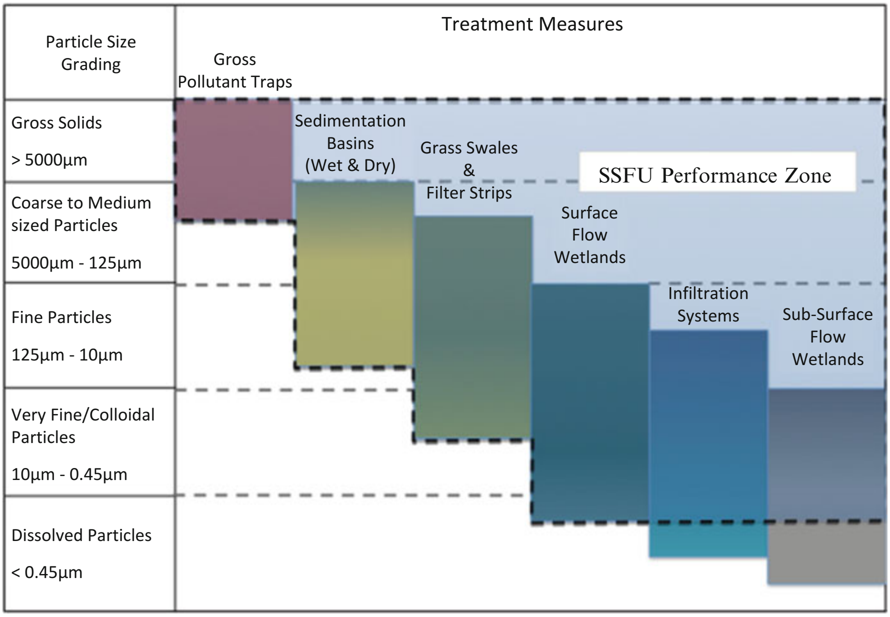
SSFU’s are available in different sizes, that are selected based on treated flow, gross flow, catchment size, catchment characteristics (that define potential load) and the sensitivity of receiving waters.

6.10 Cost Effectiveness

Table 6.2 shows the performance zone of the SSFU as an overlay to the recommended treatment measures recommended in the Engineers Australia (2006). This table overlay graphically shows how one SSFU replaces the need for a treatment train, which may include a number of measures in sequence in order to remove urban generated contaminants. In some cases when used as a pre-treatment to wetlands, the capital cost may be slightly reduced with the main benefit arising from the amenity being self sustaining and not requiring remediation on regular intervals.

Life cycle analysis shows that compliance with contaminant reduction targets can be achieved in many cases at 80 % lower cost than current treatment train measures. Installation costs are typically less than 2 % of the development capital works, with service costs consistent with monthly landscaping maintenance.

Table 6.2 Figure 1.3 in Engineers Australia (2006) overlain with SSFU performance zone



6.11 Conclusion

The installation of SSFU's distributed within a watershed in both Peri Urban and Urban areas could prevent an increase of contaminant load into the receiving water and associated ecosystem, allowing time for nature or assisted remediation to take place and restore the water health to a long term sustainable level.

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