Stormwater detention & BMPs

Rétention des débits d’orages et méthodes de gestion optimale (BMPs)

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ABSTRACT

The Paper outlines the considerations involved in stormwater hydrological and pollutant mobilisation processes, and the selection of stormwater detention and pollution control Best Management Practices (BMPs). In addition, it provides a summary of the major BMPs commonly used, including material on their purpose, description and performance. A Table is included providing broad indications of pollutant removal and flow attenuation capacities of each BMP. The non-structural range of BMPs summarised includes the modification of the use and disposal practices of household chemicals, land uses and management practices, on-site programs of runoff management, the management of pollutant build-up, and sewer infiltration management. The structural range of BMPs summarised includes infiltration and local disposal systems, retention or restoration of natural vegetated channels, inlet controls, detention basins, retention ponds and wetlands, and in-pond treatment.

RÉSUMÉ

L'article expose brièvement les principes appliqués dans les procédés de gestion des débits d’orages et des pollutions associées, ainsi que le choix des méthodes de gestion optimale (BMPs “Best Management Practices”) des rétentions des apports des orages et du contrôle de la pollution. De plus, l’article donne un résumé des méthodes BMPs les plus couramment employées, avec indication du matériel utilisé et de ses performances. Un tableau donne des indications générales sur la dépollution et la capacité d’atténuation du débit de chaque BMP. La panoplie des BMPs non structurelles présentées comprend la modification de l’usage des produits ménagers, l’utilisation des sols, les programmes de régulation locale des débits, la maîtrise des polluants et l’infiltration des effluents. La panoplie des BMPs structurelles présentées comprend les systèmes d’infiltration et d’élimination locale, la végétalisation des lits fluviaux, des organes de contrôle des apports, des bassins de rétention, des polders ainsi que le traitement par lagunage.

1 Background

The Overview outlined the changing context of urban drainage, in relation to the growing community awareness regarding the need for environmental protection, and urban stormwater resource and open space values. This paper reviews the experience in the application of a range of urban stormwater management practices, and their performance in securing protection of environmental values. It comprises an overview of catchment processes and environmental values, and an evaluation of the overall management approaches and the individual management practices.

While the primary focus of this Paper is on quality management, quantity or runoff rates are also critical, both in respect to the generation of pollutants and peak flows. Consequently, it is necessary to undertake an integrated analysis of management practices in relation to both flows and quality. Similarly, while the primary focus is on separate stormwater and sewer systems, the management practices outlined can reduce inflow of stormwater into combined systems.

2 Overview of catchment processes & environmental values

2.1 Hydrological and pollutant mobilisation processes

The natural processes of rainfall interception by vegetation and natural depressions, together with soil infiltration and storage and groundwater recharge/discharge, largely determine the volume of runoff relative to rainfall depth, and the rate of discharge. Vegetation is an important modifier of runoff processes through enhancement of interception and infiltration capacity, and evapotranspiration drawdown of soil moisture storage. Urbanisation causes major changes to the landscape. It introduces large areas of impervious surfaces, changes vegetation and soil permeability on remaining pervious areas, changes the surface drainage morphology and the interflow and throughflow to groundwater. These changes greatly increase the volume and rate of discharge and associated pollutants in stormwater runoff.

Vehicle traffic and other urban activities superimpose a range of external pollutant loads on the impervious areas. The application of fertilisers, herbicides and pesticides to pervious areas, and the resultant over-spray of these substances to adjacent impervious surfaces, can further contribute to the pollutant load on the urban landscape. Much of this deposition is mobilised by surface runoff and is transported to receiving water bodies.

The replacement of vegetated waterways or overland flow paths with pipes or concrete lined channels, and the filling and drainage of natural depressions and wetlands, substantially diminishes natural interception of runoff constituents as well. The associated increases in volumes and peak flows, especially during small rainstorms, contributes to the enhanced transport and remobilisation capacity of constituents, and exacerbates downstream flow and pollutant levels. While differences in climates, soils and urban forms and activities will result in differences in distribution of water across various runoff pathways, the basic processes remain the same. The primary focus of the stormwater management practices is to limit or prevent the changes imposed by urbanisation, or to ameliorate the impact of these changes. It is normally not feasible to return urban areas to pre-development storm water runoff response conditions, and limiting impacts to a practical level has to be the goal of stormwater management practices and programs.

2.2 Environmental values & ambient flow & quality guidelines

The major environmental value categories of urban and receiving waters commonly comprise the conservation of aquatic ecology; water-based and related recreation; landscape and open space aesthetic values; and water supply (municipal, stock, irrigation, industrial). The protection of these use values are defined in terms of ambient water quality guideline values. The principal urban stormwater flow and pollutant categories impacting on the water quality and ecology of receiving waters comprise increases in the variability and peak flows, and elevated catchment exports of sediment and suspended solids loads, BOD, nutrient, bacteria and trash and debris. Toxicants in discharges may impact on aquatic ecology.

As discussed in the Overview, the identification of the critical pollutants is an important consideration in the assessment of management practices. In the case of toxicants, both the acute (short-term effect) and chronic (long-term exposure or bio-accumulating effect) need to be considered. The interpretation of toxicants is complicated however by their rapid adsorption onto suspended particulate material, and by questions of their bio-availability.
2.3 Discharge & pollutant load reduction goals

In addition to identification of the critical pollutants, the required level of pollutant load reduction can be critical in determining the appropriateness of management measures. While the flow and water quality guidelines identify the flow regimes and ambient quality required on a continuous basis to sustain the designated environmental values, these ambient conditions need to be defined in terms of the level of permissible flows and pollutant loading consistent with the protection of the values. Unlike flood damage in which the extreme events are critical, stormwater quality impacts are related primarily to first flush and/or the cumulative effects of a large number of small scale storm events, 85 to 90 percent of which are less than a 1 in 1 year frequency (Hall, et al., 1993; Urbonas, et al., 1995). Therefore, water quality control must target the volumes typically associated with storms having a recurrence interval of usually less than 1 in 1.

2.4 Urban planning & environmental regulation administrative context

The administrative context will also have an important bearing on the assessment of the stormwater management measures. The catchment management planning-based approach considers the environmental values to be sustained, and land uses and associated management practices across the catchment that need to be provided to maintain these values. This is often a multi-objective-based process. Implementation is via planning and regulatory controls.

In the purely regulatory or licence-based administrative approach, the regulatory agencies may prescribe the BMPs to be applied across the catchment, or require the development of a management plan as the basis for licensing.

Implementation is primarily regulatory control-based. An information focussed administrative approach provides education material critical to both the catchment management strategy and regulatory-based approaches. In the absence of other formalised procedures, it may be the only available activity for influencing outcomes.

3 Review of management practices

As outlined above, catchment management strategies are used to identify the environmental values to be protected and the critical pollutant control needs. Individual management practices need to be understood in this wider metropolitan or catchment stormwater management strategy context, as well as in the context of the collective benefits arising from a treatment train-based approach. It is important to recognise that stormwater BMP design and performance assessment are still a growing engineering science. Table 1 summarises the pollutant removal ranges recorded by a number of investigators for a number of control practices. As the ranges imply, it is not possible to provide definitive designs to meet specified and consistent performance requirements at this time.

In addition to the environmental costs and benefits, a further category of considerations requiring assessment comprise the physical opportunities and constraints peculiar to the urban area. They comprise:

- greenfield development, with opportunities for an integrated quantity, quality and open space approach;
- retrofitting within existing development where open space and hydraulic head are extremely constrained;
- retrofitting within existing development where access to open space and hydraulic head exist;
- retrofitting within existing development in association with urban redevelopment, where there may be opportunities to establish new overland flow corridors and easements for the installation of BMPs;
- in-fill (greenfield) development within existing development, where drainage routes and grade may be restricted by the surrounding existing development.

Common to all are good housekeeping practices, pollutant source management (e.g., covering of loading docks), education, regulation of illegal dumping practices, and management of construction and maintenance practices. In view of the diverse range of pollutant and peak flow reduction requirements, and the local physical, social and economic constraints, the design, operation and maintenance requirements will be site specific.

Table 1. Representative Pollutant Removal and Flow Attenuation Capacities

<table>
<thead>
<tr>
<th>BMP</th>
<th>Pollutant Removal</th>
<th>Flow Attenuation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trash</td>
<td>Solids</td>
</tr>
<tr>
<td>Percolation trenches/pits</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Grassed swales</td>
<td>NA</td>
<td>■</td>
</tr>
<tr>
<td>Grassed buffer zones</td>
<td>NA</td>
<td>■</td>
</tr>
<tr>
<td>Pervious pavements</td>
<td>■</td>
<td>0</td>
</tr>
<tr>
<td>Infiltration basins</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Vegetated waterways</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>Inlet controls/traps</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Detention basins (wet, dry)</td>
<td>NA</td>
<td>■</td>
</tr>
<tr>
<td>Retention ponds/wetlands</td>
<td>NA</td>
<td>0</td>
</tr>
<tr>
<td>Aeration</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Street sweeping</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Key: Removal efficiency
- □ 80-100%
- □ 60-80%
- □ 40-60%
- □ 20-40%
- □ 0-20%
- NA - not applicable

Notes: Level of pollutant removals will be subject to the level of provision of BMP volume or surface areas relative to catchment runoff.
In the case of catchments having silty clay or clay soils, higher levels of BMP volume or surface areas relative to catchment runoff will be required to achieve these levels of removal.
Level of flow attenuation in the case of Retention Ponds & Detention Basins is a function of storm frequency, storage provision & spillway design.
Pollutant removal levels of street sweeping is dependant on equipment used and frequency of sweeping.
As a general rule, the higher the inflow pollutant concentration the greater the level of removal.
4 Technical summary of individual practices

A. Non-structural best management practices

i) Modify use & disposal practices of household materials  
*Purpose:* To promote the use and management of household chemicals, pesticides, solvents, oils, fertilisers, antifreeze, etc. such as to minimise the potential for washoff or leaching or direct disposal into the stormwater system.

*Description:* This group of BMPs comprises:

- the education of the community regarding the potential impacts of common household chemicals on water quality and aquatic ecology, the provision of information on good practices and available disposal services, and on the receiving water in respect to stormwater discharges;
- the use of planning, environmental and building ordinances and regulations to control use of materials or practices having the potential to impact on water quality and ecology; and
- the provision of information and guidelines and display sites demonstrating environmentally sensitive practices.

There has been wide application of these approaches. While it is difficult to assess the overall effectiveness of these programs, their application has yielded greater public awareness of the impacts of disposal practices, and hopefully, a reduction of pollutants reaching receiving waters.

ii) Land uses and management practices  
*Purpose:* To minimise the potential for pollutant generation as a result of land development, and to protect significant hydrological and terrestrial features of the proposed development site.

*Description:* The adoption of land use capability assessment mapping and land use zoning and management practices consistent with minimising the effects of urbanisation on receiving waters.

*Performance:* Generally, this is an accepted practice for all new development. The lack of documented management techniques for different hazard conditions often limits the systematic application of this approach.

iii) On-site programs of runoff management  
*Purpose:* To minimise runoff and the export of pollutants from house blocks, construction or industrial sites.

*Description:* This group of BMPs comprises a range of measures, including:

- minimisation of impervious areas and the direction of impervious area drainage to on-site pervious areas;
- maintenance of vegetative cover or mulching;
- provision of on-site interception and retention of runoff from construction, chemical and other handling and storage areas;
- the revision of municipal standards to promote on-site detention and retention of stormwater.
Performance: Wide application of these Practices is considered cost effective for minimising pollution.

iv) Management of pollutant build-up

Purpose: To reduce the discharge of pollutants to stormwater systems, by limiting the at-source build-up of pollutants on impervious surfaces, or those collected locally in stormwater gullies or catchpits.

Description: Management Practices within this category comprise the use of mechanical equipment for street sweeping, washing and vacuuming, to remove the build up; the use of gully mechanical cleansing equipment to remove gully sediment and other material; and the provision of an effective solid waste management program.

Street sweeping/washing and gully eduction are widely adopted municipal practices, established primarily to maintain safety and aesthetic standards, and to maintain the hydraulic capacity of the installed stormwater system. With a growing perception of the stormwater pollution control benefits of this Practice, there has been a shift to vacuuming based mechanical equipment. Research and development is proceeding into the adaptation of stormwater entry pits to provide a more effective trash and sediment interception control. There is also a growing recognition of the inter-dependence of waste streams, and the need for the provision of effective and comprehensive solid waste management program, to minimise illegal dumping of wastes, and to shift away from inappropriate water borne waste disposal.

Performance: While street sweeping is recognised as an effective means for removing debris and gross pollutants from the street surface, the effectiveness in water quality control terms is questionable. The US NURP program (US EPA, 1983) did not find street sweeping leading to statistically significant reductions in runoff Equivalent Mean Concentrations (EMCs), and the potential benefits were masked by data variability. Further research is continuing.

v) Sewer infiltration management

Purpose: For separate sewer and stormwater systems, to minimise the potential for sewer overflows associated with stormwater infiltration and discharges into sewers.

Description: This group of BMPs comprises a range of measures, including:

- the use of plastic and other sewer pipe materials minimising the number of open joints;
- the rehabilitation (lining) of ageing sewers;
- the detection and remediation of illegal stormwater connections; and
- the establishment of sewer block and break detection and remediation programs.

These Practices are being implemented by sewerage authorities on a case-by-case basis when wastewater infiltration problems are detected and are judged to be a significant problem.

B. Structural best management practices

i) Infiltration & local disposal systems

Purpose: To promote the interception of surface runoff and infiltration into the soil and groundwater to reduce surface runoff, peak flows and associated pollutant mobilisation and transport, and to promote groundwater recharge.

Description: These Practices provide for the interception and infiltration of stormwater through the use of:

- mulching and vegetation on pervious surfaces, and their protection against compaction by vehicles or pedestrians;
- grassed swales and grassed filter strips;
- rock-filled percolation trenches or pits for temporary stormwater storage and infiltration;
- underground or “at-surface” linear prismatic exfiltration trenches, for the interception, temporary storage and infiltration of stormwater;
- infiltration basins to provide temporary surface storage and infiltration of stormwater; and
- porous pavements to enable stormwater infiltration into the sub-base and soil.

Swales, filter strips or soakage pits may be integrated into landscape treatment of public or private open space areas, or into the streetscape. They also provide benefits in terms of restoring a more natural local water balance.

Exfiltration trenches are located to collect runoff from several lots/properties, thereby reducing runoff volume, peak flows and pollutants from frequent events. Trenches generally serve small drainage areas (< 2 ha), requiring some runoff pretreatment to reduce the influx of solids and premature clogging, and are only feasible in soils with good percolation capacity, and locations with water table and bedrock situated well below the trench bottom.
Constraints to their wide application include steep slopes or erodible soils; active clays; and perched groundwater table areas. Care is required to ensure that water supply aquifers are not contaminated as a result of recharge by polluted stormwater. Several different types of porous pavement are used in urban areas – porous asphalt, porous concrete, perforated concrete blocks, and artificial turf; all of these can be used with or without a storage reservoir under the pavement, filled with gravel or rock. Constraints to the application of this Practice include vehicle loadings, volume of traffic, risk of hazardous chemical spills, and steep slopes.

Performance: While the local interception and detention storage of swales and pits reduce the peak discharge from local areas, or for larger areas for smaller events, their effectiveness is diminished for major events due to the greater probability of soil moisture saturation (less available soil storage) under those conditions. The practices are effective in enhancing soil moisture and associated sustainability of surface vegetative cover, thereby enhancing the armouring of surfaces against erosion, and the interception of particulates. There is reported however, a high level of failure of infiltration based techniques, often resulting from inappropriate sizing relative to the catchment area, lack of pre-treatment and maintenance, and groundwater mounding. The build-up of groundwater mounding and the sealing of infiltration surfaces are the two major causes of failure of infiltration basins. The provision of pre-treatment to intercept fines is critical to the protection of the porosity of surface soils and groundwater quality.

Exfiltration trenches help to reduce runoff peaks for frequent storms, reduce runoff volumes, enhance groundwater recharge and provide moderate to high removals of such stormwater pollutants as suspended solids, phosphorus, nitrogen, oxygen demanding substances, trace metals and bacteria. Good design and maintenance are very important; a high percentage of these structures fail because of clogging or ground water mounding. Well-operating porous pavements reduce surface runoff, with smaller storm runoff being contained completely, reduce runoff peaks by runoff interception and storage in the underground reservoir, and enhance percolating runoff quality by filtration through the pavement and sorption of pollutants onto fill materials (Azzout et al., 1994; Pratt et al., 1995). Regular maintenance with special equipment, sometimes using high pressure spraying and suction, is required to sustain good performance of these systems. There has been a high rate of failure of monolithic porous asphalt and concrete in eastern U.S.A., and abandonment of this practice in other countries.

ii) Retention or restoration of natural vegetated channels
Purpose: To utilise or restore natural stream channels and floodways within urban areas or to construct vegetated channels to secure economies, retard discharges and reduce peak flows, and to enhance the interception of suspended solids and nutrients and open space and landscape values.

Description: Where natural or restored streams have sufficient hydraulic capacity, and are sufficiently stable to sustain elevated flows, they can provide substantial economic, environmental and social benefits (Lawrence et al., 1995). Extensive planting is used to armour channel surfaces against erosion, reduce velocities and provide an attractive open space – landscape corridor. The capacity of natural streams and landscaped waterways to store large volumes of water (flood routing), reduces the peak flow propagation downstream associated with hard-lined channel designs.
In the case of the constructed vegetated channels, the provision of a small concrete or stone dry weather flow channel or pipe is suggested to enable drainage of grassed inverts between storms. Control is also required over the rate of sediment deposition, to ensure the viability of grass and other ground covers. A common approach is the requirement for Gross Pollutant Traps on drains discharging to a natural or constructed vegetated channel. The traps also control litter.

The restoration or construction of vegetated channels in respect to enhancement of stream ecology is complex. If it is accepted that disequilibrium and disturbance is the “normal” condition for urban waterways/channels, then the goal of ecological sustainable development of the channel becomes the restoration of the entire spectrum of low to high frequency perturbations. Ecosystem recovery analysis is needed to ensure the success of a sustainable restored stream.

There are movements across almost all countries to recover, at least in part, the stream values of urban drainage corridors. The application of this approach is rapidly gaining acceptance, in view of its enhancement of adjacent land values, its more environmentally sympathetic treatment, and the open space values it affords. One of the implementation difficulties associated with the approach is the vulnerability of channel surfaces pending establishment of the vegetation armouring and biomass necessary to achieve the design hydraulic roughness coefficients (Mannings $n$ of 0.04–0.055). Unless the dry weather flow channel or pipe incorporates capacity for sediment transport, there will be a requirement to intercept stormwater sediment prior to discharge into the natural stream/waterway, in order to sustain channel grass cover.

**Performance:** The Practice represents a low cost solution as compared to concrete pipes or channels, and affords enhanced land, open space and recreation values, and opportunities for conservation of riparian and wetland habitats and related biota. The enhanced in-channel water storage can reduce the velocities and peaking of downstream storm flow, and enhance the sedimentation of suspended solids and associated pollutants during storm flows.

**iii) Inlet controls (gross pollutant traps & filter inlets)**

**Purpose:** To intercept litter, trash and organic debris, and coarse silt and larger fractions in stormwater discharges to help protect the physical and biological functions and open space values of downstream waterways, and to protect groundwater quality and infiltration zones.

**Description:** Techniques utilised include fixed screens and open baskets located across flow paths to intercept suspended and floating solids; floating booms or fixed baffles to intercept floating solids, scums and oil; sedimentation basins to intercept settleable solids; fine screens (swirl separators, geo-fabric booms) to separate trash and other suspended solids; and sand or other media filters to
intercept fine suspended solids. The Traps may be located on main drainage lines, or may be inte­
grated into drainage entry pits or inlets. The basins may be open, for easy removal of material, or in
ground and covered, consistent with meeting local landscape requirements. Collected solids may be
removed by excavator, back-hoe or gully cleansing truck and transported to landfill areas, or be
treated and re-used as a soil conditioner.

There has been extensive application of gross pollutant traps, sometimes adopted under the mis­
conception that they remove a wide range of pollutants. They can be an important component of the
treatment train. Gross pollutant traps can have significant head losses, necessitating careful
hydraulic design. In other respects, they are usually compact, and can sometimes be retrofitted into
established urban areas. The high organic nature of solids they remove is difficult to handle, and
research is proceeding on different handling techniques and insitu chemical and biological
treatment. Unless maintained on a routine basis, odour complaints can occur. Maintenance costs
can be high; in-situ treatment can transform trapped material into a well aerated soil conditioner
having economic value. Filter inlets are a high cost and extremely high maintenance solution, and
are limited to areas where available land is at a premium.

**Performance:** The traps are extremely effective in interception of coarser sediment fractions, trash
and debris. Their limited hydraulic capacity in respect to screening can result in their over-topping
and reduced effectiveness for significant storm events. Filter inlets or basins are reported as achiev­
ing a high interception level for suspended solids, phosphorus, BOD, heavy metals. They do plug
quickly and need consistent maintenance to function properly (Urbonas, 1996). Plugged filters
back-up stormwater, causing surface flooding or stormwater bypass.

iv) **Detention basins**

**Purpose:** To temporarily store flows for sufficient time to enable reduction in downstream storm­
water or sewer pipe flows to levels which can be accommodated without exceeding hydraulic
capacity. Extended detention basins may also provide suspended solids and other pollutant inter­
ception capacity, but this is often secondary to their primary hydraulic flow retardation function.

**Description:** Detention basins range from swales within residential blocks, to major basins servic­
ing an entire catchment. They comprise an impoundment created by an embankment or excavation,
and by restriction of their outlet flow capacity. Their use for stormwater pollution control requires extended stormwater detention (24 to 48 hours), to enable sedimentation of suspended solids and associated nutrients, oxygen demanding substances, organic material and bacteria. There has been wide adoption of stormwater detention basins, mainly associated with urban development within catchments in which there are downstream hydraulic constraints through established urban areas. Detention can also reduce the extent of major infrastructure augmentation works downstream. Detention basins are also being adopted for water quality enhancement and as part of a wider pollution control treatment train. Attention is required in their design to ensure the safe spillage of excess flows, such that life and property are not at risk downstream, and to ensure the provision of community safety. Close attention is also required to the potential for flood impacts resulting from their backwater effects.

Performance: Properly designed extended detention basins can achieve significant pollutant removals. The combined use of detention basins as flood and pollutant controls can yield economic benefits in terms of deferment of costly hydraulic infrastructure augmentation downstream and the provision of alternative water pollution interception measures. The use of on-site detention basins has become popular with local governments in many countries, partly in view of the authorities ability to transfer the cost of their construction to the land development. However, there are growing concerns regarding the ability to ensure their proper maintenance and operation in the longer term.

v) Retention basins, ponds & wetlands
Purpose: To establish a permanent water impoundment and aquatic plants as the basis for the interception of suspended solids, nutrients, toxicants and bacteria.
Description: Retention ponds are small lakes with a permanent pool of water and some emergent vegetation, while wetlands are shallow basins with most of the surface covered by emergent vegetation. The retention of water enables settling of suspended material, contact with and adsorption by active sediments, and interception and take-up by emergent and submerged plants, algae and fauna. The interception of the gross sediment and trash before discharge into a pond or wetland, is very important to their function. Ponds and wetlands require minimal maintenance, and provide significant open space/landscape enhancement and constitute a productive ecosystem.

In the case of combined sewer systems, retention basins will be subject to much more intensive sediment and organic loading, and will require periodic removal of accumulated material to prevent re-mobilisation as a result of biological reduction processes. Basins in this context are more likely to be concrete lined, as necessary to undertake periodic removal of accumulated material. Wetlands in this situation are more likely to comprise gravel beds with emphasis on plant take-up and harvesting.

There has been extensive application of this Practice in many countries. There are questions regarding the adequacy of storage volume provided in many cases. Concerns have been raised regarding the potential for nuisance mosquito breeding, but with appropriate attention to edge treatment and shaping, this does not appear to be a major problem.

Physical constraints limiting the application of this practice include open space requirements, and hydraulic constraints associated with potential backwater impacts. Given the high peak nature of urban runoff events, the performance of wetlands will be constrained by their limited hydraulic retention time, unless incorporated together with substantial hydraulic detention. This requirement is addressed in two possible ways; the combination of flow detention capacity and pond/wetland processes within the one basin (wet detention basin), or the adoption of treatment train comprising upstream flow detention basins followed by a downstream retention pond or wetland. Sediment and trash interception prior to discharge into ponds or wetlands is required in order to protect the emergent and submerged plants, defer the need for costly and disruptive dredging, and to protect the landscape quality. The cost of maintaining ponds and wetlands is significantly less than for an equivalent area of parkland (Lawrence et al., 1995). Subject to gentle grading of edges, community concerns regarding the risk of small children drowning has not been an issue.

Performance: The performance of retention ponds is a function of their hydraulic retention time, the organic loading (BOD) on ponds (potential to de-oxygenate the sediments, resulting in the remobilisation of pollutants), and the depth of the ponds (minimise the potential for thermal stratification). Depths typically need to be limited to 1.5 to 3.0 m, but greater depths in some instances have been satisfactory. The promotion of emergent aquatic plant growth, namely the establishment of littoral zones, significantly enhances the performance of ponds.

Suspended solids and total phosphorus interception rates are reported at 50 to 70% at 10 days, to 80 to 90% at 30 days retention time (Lawrence et al., 1995). On-line ponds are most common, but offline ponds are adopted in some communities. Reports generally agree on the variability in removal effectiveness, including the possibility of negative efficiencies for individual events where short-circuiting enhances resuspension, or high BOD associated with the event leads to de-oxygenation of the sediments and release of pollutants. Whilst overall, fairly high levels of performance might be expected, it is important to recognise that currently design models are limited in their capacity to predict either event based or annual removal efficiency. Consequently, caution is urged when developing stormwater management practices and regulatory approaches. Ponds/wetlands are also perceived by the community as valuable conservation and landscape features, attracting a diverse
range of water birds and aquatic biota. However, large flocks of birds can also constitute a point source of contamination, reducing the pollution interception function of the facility.

vi) In-pond physical, chemical & biological treatment

*Purpose:* To enhance the pollutant interception performance, and/or ecological and beneficial use values of lakes, ponds and wetlands by direct physical or chemical treatment or by biological manipulation.

*Description:* Management Practices within this category comprise a wide range of physical, chemical and biological treatment techniques, including:

- use of surface mixers or suspended air roses to destratify and mix waters of ponds and lakes;
- application of chemicals (alum or gypsum) to enhance the coagulation & sedimentation of suspended fines;
- treatment of sediments with nitrate N, to re-establish their adsorption capacity;
- harvesting of aquatic plants or algae, as a means of maintaining a nutrient uptake capacity and removal.

The removal of sediment to re-establish or maintain pond volume is an ongoing maintenance requirement.

Research has demonstrated that in Australia, ponds having an elevated turbidity under hot summer conditions are subject to temperature stratification, even at depths as shallow as 2 metres. In these cases, opportunities exist for reduction in remobilisation of pollutants by the application of aeration techniques. In the case of Inlet Traps, the treated material would be more economically attractive for re-use as a soil conditioner. Chemical treatment to enhance coagulation and sedimentation of suspended fines, is widely used in Australia in association with off-stream interception ponds on construction sites. There are however concerns regarding the ecological impact of adding large quantities of chemicals to stream systems. Sediment renovation using nitrate N injection has been applied in Germany and Sweden. Sediment bio-remediation techniques are being assessed in a number of countries.

There is now wide recognition of the importance of aquatic macro-plants in enhancing the interception of suspended solids and nutrients, in re-aerating the sediments and thereby limiting nutrient release, and in transforming carbon into less biologically available forms. While there has been wide application of weed harvesting, this has focussed more on clearing weeds from recreation areas than on water quality management. Stocking of lakes and ponds to enhance the recreational fishery may result in overgrazing of zooplankton, resulting in significant increases in algal numbers.

*Performance:* The application of aeration practices have the potential to yield significant improvement in interception performance in some cases, while chemical treatment is limited to special applications. The literature suggests limited benefits in harvesting aquatic plants in terms of nutrient interception of stormwater wetlands and ponds.

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