5 Detention Systems

5.1 Dry/Ephemeral Detention Areas

Background

Dry/ephemeral detention areas are landscaped areas formed by simple dam walls, by excavation below ground level or by utilisation or enhancement of natural swales or depressions. These areas primarily serve to capture and store stormwater to prevent excessive runoff and channel erosion in receiving environments, and as areas to remove particulate-based contaminants and sediment.

These areas are termed dry/ephemeral as they have a base level located at or above the regional groundwater level (typically defined as the long-term maximum groundwater level), with inundation of the area occurring as a result of intermittent stormwater inundation, rather than as a result of groundwater exposure.

The Department of Water is currently not including constructed ponds and lakes as a stormwater quality improvement BMP in this manual. This applies to designs that involve artificial exposure of groundwater (e.g. through excavation, or lined lakes that require groundwater to maintain water levels in dry seasons) or the modification of a wetland type (e.g. converting a damland into a lake) due to water conservation, environmental and health concerns.

For information regarding the Department of Water’s current position on the construction of ponds and lakes, the reader is referred to the Interim Drainage and Water Management Position Statement: Constructed Lakes (Department of Water 2007).

In order for detention areas to perform their design function of detaining flows, the storage volume needs to be available for the next storm event, therefore maintaining a permanent pool is not considered best practice.

Performance efficiency

Dry/ephemeral detention areas are effective at removing particulate-based contaminants and sediment but less effective for treatment of soluble pollutants where biological uptake of nutrients is required. Pollutant removal through sedimentation relies on strong affinity for sorption of metals, nutrients and hydrocarbon contaminants with particulates. Pollutant removal efficiency increases with increasing hydraulic residence times.
There is little local data to assess the performance efficiency of dry/ephemeral detention areas. These systems however operate with a similar principle to sedimentation basins, which have been assessed. Fletcher et al. (2003) examined the performance of sedimentation basins in removing pollutants, such as total suspended solids, total phosphorus, total nitrogen and heavy metals, and the results are presented in Table 1.

Due to the infiltration capacity of sandy coastal plain soils, it would be expected that the performance efficiency of dry/ephemeral detention areas for many parts of WA would be at the higher end (or in excess) of the expected removal percentages shown in Table 1.

Table 1. Typical annual pollutant load removal efficiencies for sedimentation basins

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Expected removal</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litter</td>
<td>&gt;95%</td>
<td>Subject to appropriate hydrologic control. Litter and coarse organic matter should ideally be removed in an aerobic environment prior to a basin, to reduce potential impacts on biological oxygen demand.</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>50–80%</td>
<td>Depends on particle size distribution.</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>20–60%</td>
<td>Depends on speciation and detention time.</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td>50–75%</td>
<td>Depends on speciation and particle size distribution. Will be greater where a high proportion of phosphorus is particulate.</td>
</tr>
<tr>
<td>Coarse sediment</td>
<td>&gt;95%</td>
<td>Subject to appropriate hydrologic control.</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>40–70%</td>
<td>Quite variable, dependent on particle size distribution, ionic charge, attachment to sediment (vs % soluble), detention time, etc.</td>
</tr>
</tbody>
</table>

Source: Fletcher et al. (2003)

Cost

Construction costs associated with these facilities can vary considerably.

The variability can be attributed to whether the existing topography will support the function of a dry ephemeral detention area, the complexity of the outlet structure, and whether it is installed as part of new construction or implemented as a retrofit of an existing drainage system. Varying subsurface conditions and labour rates can also contribute to the inconsistent costs.

Local cost data for dry/ephemeral detention systems is limited. An alternative method of costing these systems is to examine the costs of similar systems, such as ponds and swales. Center for Watershed Protection (1998) cited in United States Environmental Protection Agency (2001); Fletcher et al. (2003) cited in Taylor (2005) and Walsh (2001); Weber (2001) cited in Taylor and Wong (2002) reported costs for ponds (sourced from limited data in Australia) ranging from $2 000/ha of catchment to $30 000/ML of pond volume, and $60 000/ha of pond area.

Taylor (2005) also reported costs for vegetated swales of approximately $4.50/m², which included earthworks, labour and hydro-mulching. For swales with rolled turf the cost was approximately $9.50/m² and for a vegetated swale with indigenous species the cost was approximately $15–20/m².

It would be expected that the above costs for both these systems would be comparable to the components of a landscaped dry/ephemeral detention area.
Center for Watershed Protection (1998), cited in United States Environmental Protection Agency (2001), estimated the annual cost of routine maintenance for ponds at typically about 3-6% of the construction costs. However, there is almost no actual maintenance cost data available in published literature and studies carried out have yet to experience the full maintenance cycle.

Maintenance costs may vary considerably depending on the aggressiveness of the vegetation management required at the site and the frequency of litter removal.

**Design considerations**

The design approach should be selected based on the target pollutants as well as site and economic constraints.

As with other BMPs, pre-treatment can extend the functional life and increase the pollutant removal capability of ephemeral detention areas. Pre-treatment can reduce incoming velocities and capture coarser sediments, which will reduce the maintenance requirements and extend the life of the detention system. This is usually accomplished through means such as buffer strips and/or gross pollutant traps.

Forebays (or inlet zones) at the inflow points to the detention area can capture coarse sediment, litter and debris, which will simplify and reduce the frequency of maintenance. Forebays can be sized to hold either the expected sediment volume between clean-outs, and/or designed to have sufficient capacity to detain or infiltrate (where possible) frequently occurring storm events (typically < 1 year ARI) without discharge to the main ephemeral detention area.

Construction of dry/ephemeral detention areas has lower acid sulphate soil (ASS) risks compared to risks associated with construction of ponds and lakes, as dry/ephemeral detention areas should be designed to not alter groundwater levels, which could result in flooding or exposing ASS. ASS however must still be considered when designing in areas that have a high risk of forming ASS, or where dewatering during construction in medium and low risk areas could affect soils in high risk areas. These areas are defined in ASS risk mapping available from the Department of Environment and Conservation and in Planning Bulletin 64: *Acid Sulphate Soils* (Western Australian Planning Commission 2003). Land development proposals within these areas will typically be required to undertake site specific soil investigations and prepare ASS management plans and, where relevant, dewatering management plans.

Dry/ephemeral detention areas must be designed to minimise the risk of mosquito breeding. See Section 1.7.7 ‘Public health and safety’ of the Introduction section of this chapter for more information on mosquito management. Some of the mosquito management guidelines in the Constructed Wetlands BMP may also be applicable for dry/ephemeral detention areas.

**Design guidelines**

**Design flows**

The *Decision Process for Stormwater Management in WA* (Department of Environment & Swan River Trust 2005) provides general design flow criteria guidance for the use of landscaped dry/ephemeral detention areas in public open space areas or linear multiple use corridors.

To protect receiving environments from flooding and erosion and to maintain ecological water requirements, the generally adopted approach for design is to maintain pre-development discharge rates for storm events up to the 100 year ARI, with events up to the 1 year ARI retained or detained on-site or as high in the catchment as possible. As discussed in the Design Considerations section of this BMP, this may result in the use of forebay/inlet zone areas to maintain frequently occurring storms separate from the main dry/ephemeral detention area.
A range of hydrologic methods can be applied to estimate design flows. If the catchment is relatively small, the Rational Design Method (Institution of Engineers Australia 2001) may be used for sizing of inlet hydraulic structures.

It is recommended however that the detention area sizing, design configuration and design of outlet structures (pipes, spillways, etc.) be undertaken using a comprehensive flood routing method. If required, the Department of Water can provide advice on suitable hydrologic/hydraulic models to undertake this design.

The typical approach to estimate the design flow is to establish a pre-development model of the catchment area. The model is used to estimate the pre-development flow rates from the contributing catchment under its current land use. Where possible, modelled pre-development flow rate estimates should be verified against any existing historical data or anecdotal information.

Note that in some areas the pre-development flow rate may exceed the capacity of the downstream receiving environment, and the design flow estimate may need to be reduced accordingly to protect the receiving environment.

**Basin layout**

To optimise hydraulic efficiencies and thereby reduce the potential for short-circuiting and dead zones, it is desirable to adopt a high length to width ratio. The ratio of length to width varies depending on the size of the system and the site characteristics. To minimise earthworks, smaller systems have typically been built with low length to width ratios, which has often led to poor hydrodynamic conditions.

The term ‘hydraulic efficiency’ was used by Persson et al. (1999) to define the expected hydrodynamic conditions of stormwater detention systems. Engineers Australia (2006) presented a range of expected hydraulic efficiencies for detention systems for a series of notional shapes, aspect ratios and inlet/outlet placements. It was recommended that such systems should achieve a minimum hydraulic efficiency of 0.5, but ideally should be designed to promote values greater than 0.7 (Figure 3).

![Diagram of Basin Layout](image)

**Figure 3.** Hydraulic Efficiency ($\lambda$) is a quantitative measure of flow hydrodynamic conditions in constructed wetlands and basins. $\lambda$ ranges from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment. (Source: Engineers Australia 2006.)
Note that in Figure 3, the circles in diagrams O and P represent islands in a basin and the double line in diagram Q represents a structure to distribute flows evenly.

There can often be multiple inlets to the basin and the locations of these inlets relative to the outlet structure can influence the hydraulic efficiency of the system. Inlet structure designs should aim to reduce localised water eddies and promote good mixing of water within the immediate vicinity of the inlet.

**Forebay/inlet zone**

The forebay/inlet zone is a transitional zone between the stormwater outfall and the main ephemeral detention area. The function of the inlet forebay ranges from providing a sedimentation area to providing a small ephemeral wetland area that stores frequently occurring storm events.

A notional required forebay/inlet zone area can be computed by the use of sedimentation theory, targeting the 125 µm sediment (settling velocity of 11 mm/s) operating at the 1 year ARI peak discharge. The specification of the required area (A) for sedimentation is detailed in Engineers Australia (2006) (based on Fair and Geyer 1954) for systems with no permanent water pool:

\[ R = 1 - \left(1 + \frac{V_s A}{nQ}\right)^n \]

Where:

- \( R \) = fraction of target sediment removed
- \( V_s \) = settling velocity of target sediment
- \( Q \) = rate of applied flow
- \( A \) = basin surface area
- \( n \) = turbulence or short-circuiting parameter

Typical settling velocities of sediments can be estimated using the values listed in Table 2. The above expression for sedimentation is applied with ‘n’ being a turbulence parameter. Figure 3 provides guidance on selecting an appropriate ‘n’ value (according to the configuration of the basin). ‘n’ is selected using the following relationship:

\[ n = \frac{1}{1 - \lambda} \]

Where:

- \( n \) = turbulence or short-circuiting parameter
- \( \lambda \) = hydraulic efficiency, ranging from 0 to 1, with 1 representing the best hydrodynamic conditions for stormwater treatment.

**Table 2. Settling velocities for various particle sizes under ideal conditions**

<table>
<thead>
<tr>
<th>Classification of particle size</th>
<th>Particle diameter (µm)</th>
<th>Settling velocities (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very coarse sand</td>
<td>2 000</td>
<td>200</td>
</tr>
<tr>
<td>Coarse sand</td>
<td>1 000</td>
<td>100</td>
</tr>
<tr>
<td>Medium sand</td>
<td>500</td>
<td>53</td>
</tr>
<tr>
<td>Fine sand</td>
<td>250</td>
<td>26</td>
</tr>
<tr>
<td>Very fine sand</td>
<td>125</td>
<td>11</td>
</tr>
<tr>
<td>Coarse silt</td>
<td>62</td>
<td>2.3</td>
</tr>
<tr>
<td>Medium silt</td>
<td>31</td>
<td>0.66</td>
</tr>
<tr>
<td>Fine silt</td>
<td>16</td>
<td>0.18</td>
</tr>
<tr>
<td>Very fine silt</td>
<td>8</td>
<td>0.04</td>
</tr>
<tr>
<td>Clay</td>
<td>4</td>
<td>0.011</td>
</tr>
</tbody>
</table>

(Source: Engineers Australia 2006.)
Hydraulic structures

Hydraulic structures are required at the inlet and outlet of the detention area. Their function is essentially one of conveyance of flow, with provisions for energy dissipation at the inlet structure and extended detention at the outlet.

Discharge of stormwater into the dry/ephemeral detention area may be via a forebay/inlet zone or direct input. It is essential that inflow energy is adequately dissipated to prevent localised scour in the vicinity of pipe outfalls. Design of stormwater pipe outfall structures is common hydraulic engineering practice. Litter control is normally required at the inlet structure. It is generally recommended that some form of gross pollutant trap be installed as part of the inlet structure. Conveyance of flow to the detention area may be via an overland flow system, such as a swale or living stream, which will provide some pre-treatment.

Configuration of the outlet structure is largely dependent on the required operation of the system during periods of high inflows. The outlet structure typically consists of two components: the outlet pit and outlet culvert. In areas of low topographic relief, the outlet structure may consist of a single outlet culvert without an outlet pit.

The computation of the required outlet culvert is an essential element of the retarding basin design and will be based on flood routing computations, as outlined in *Australian Rainfall and Runoff* (Institution of Engineers Australia 2001).

The main function of the outlet pit is to connect the detention area to the outlet culvert. Design considerations of the outlet pit include the following:

- ensure that the crest of the pit is set at the invert of the detention area to allow the area to drain completely following a storm event;
- ensure that the dimension of the pit provides a discharge capacity that is greater than the discharge capacity of the outlet culvert;
- provide protection against clogging by flood debris.

In computing the dimension of the pit, two flow conditions need to be considered. Firstly, the weir flow condition when free outfall conditions occur over the pit (usually when the extended detention storage of the retarding basin is only partially used):

\[
P = \frac{Q_d}{C_w H^{1.5}}
\]

Where:

- \( P \) = Perimeter of the outlet pit (m)
- \( H \) = Depth of water above the crest of the outlet pit (m)
- \( Q_d \) = Design discharge (m\(^3\)/s)

The second flow condition for consideration is the orifice flow condition, when the outlet pit is completely submerged (corresponding to conditions associated with larger flood events):

\[
A_o = \frac{Q_d}{C_o \sqrt{2gH}}
\]

Where:

- \( C_o \) = Orifice Discharge Coefficient (0.6)
- \( H \) = Depth of water above the centroid of the orifice (m)
\[ A_o = \text{Orifice area (m}^2\text{)} \]
\[ Q_d = \text{Design discharge (m}^3\text{/s)} \]

The orifice flow condition provides the critical condition in terms of design capacity.

Note the above equations assume the outlet pit is freely discharging and operating under inlet control. Should outlet control conditions (i.e. backwater effects) be likely for the proposed outlet structure design, then flood routing computations are recommended.

The additional provision of an overflow route for extreme events is standard design practice to ensure that overflow from the detention area can be safely conveyed either by the use of a spillway or ensuring that any embankments are designed to withstand overtopping. This issue requires specialist design input on a case by case basis and is therefore not discussed further in this document.

Vegetation specification

Plant species for the forebay/inlet zone area will typically be predominantly ephemeral wetland species. Suitable indigenous plant species will vary depending on the location of the site. Local revegetation expertise should be sought. Suggested plant species suitable for the forebay area of detention systems on the Swan Coastal Plain and their recommended planting density are detailed in the Constructed Wetland BMP.

Vegetation within the main dry/ephemeral basin area will vary and may range from existing remnant vegetation, to grassed public open space, to ephemeral wetland species (or a combination).

Maintenance

The maintenance plan should include removal of accumulated litter and debris in the detention area at the middle and end of the wet season. The frequency of this activity may be altered to meet specific site conditions and aesthetic considerations.

Biannual inspections for sediment accumulation, pest burrows, structural integrity of the outlet, and litter accumulation are typical. In parkland settings, maintenance plans should also address irrigation, nutrient and pest management issues. Accumulated sediment in the forebay should be removed about every 5-7 years or when the accumulated sediment volume exceeds 10% of the basin volume. Sediment removal may not be required in the main detention area for as long as 20 years. Refer to BMP 2.2.2 ‘Maintenance of the stormwater network’ in Chapter 7 for further guidance on managing sediments removed from the stormwater system.

Vegetation harvesting should be timed so that it has minimal impact on factors such as bird breeding and there is time for re-growth for runoff treatment purposes before the wet season.

References and further reading


Department of Water (in publication), Interim Drainage and Water Management Position Statement: Constructed Lakes, Department of Water, Perth, Western Australia.
Engineers Australia 2006, *Australian Runoff Quality – a guide to water sensitive urban design*, Wong, T. H. F. (Editor-in-Chief), Engineers Media, Crows Nest, New South Wales.


