These guidelines are based on work undertaken by two independent firms of consulting engineers – The Sustainability Workshop (Mark Liebman) and footprint (nsw) pty ltd (Ashley Bond) on commission from HydroCon. Initial work on development of MUSIC parameters for HydroCon pipe systems was undertaken by Dr Jaya Kandasamy on behalf of accessUTS Pty Ltd, also under commission from HydroCon. The document has benefitted from critical review by prominent stormwater engineers.
1. Introduction

This document provides guidance to designers wishing to incorporate HydroCon permeable concrete pipes in their designs. The document aims to show designers how MUSIC (Model for Urban Stormwater Improvement Conceptualisation) software can be used to:

1. configure a water quality treatment system incorporating HydroCon pipes;
2. calculate the number of pipes required.

The document provides two examples of the use of HydroCon pipes in bioretention systems: (1) where surface storage is available; and (2) where surface storage is limited or unavailable.

Readers are assumed to have a working knowledge of MUSIC Version 4.

2. What are HydroCon pipes?

HydroCon permeable concrete pipes are intended for management and treatment of stormwater ‘at source’. They were developed in Germany in the early 1970s as a treatment device for protection of groundwater.

HydroCon pipes are manufactured in Australia from crushed rock (virgin basalt) to a carefully formulated concrete mix designed to achieve a level of permeability based on 10% voids. Pipes have an internal diameter of 500 mm and a length of 1 m. The dry weight of a standard pipe is 240 kg. Detailed information on HydroCon pipe systems is available on the HydroCon website at www.hydrocon.com.au.

HydroCon pipes require a terminating configuration and an overflow mechanism to allow water to surcharge when flows exceed HydroCon pipeline storage capacities. HydroCon pipes should not be connected directly to outflow pipes. A terminating configuration ensures that flow velocities within a HydroCon pipeline are very low.
HydroCon pipelines are often terminated with a HydroCon ‘end plated pipe’ – shown below being levered into position.

Stormwater pits may also be used to terminate HydroCon pipelines in systems where surcharge from more than one pit is desirable or where pipelines are longer than 40 m. Using more pits will help to distribute the stormwater more evenly across the surface of the bioretention or media filtration system.

Exfiltration rates from HydroCon pipes have been tested under laboratory conditions and are reported below in Table 1. It is recommended that 50% of the unimpeded reported rate be adopted to allow for accumulation of sediment on the walls of the pipes. Where there is a high risk of flooding, designers must ensure that a fail-safe system is put in place to account for the possibility of the pipes having a highly reduced permeability at the end of their maintenance cycle.

<table>
<thead>
<tr>
<th>Pressure head above the pipe obvert</th>
<th>Minimum unimpeded exfiltration rate</th>
<th>Impeded minimum exfiltration rate (50% of unimpeded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>l/s/m of pipe</td>
<td>l/s/m of pipe</td>
</tr>
<tr>
<td>0.15</td>
<td>1.2</td>
<td>0.60</td>
</tr>
<tr>
<td>0.65</td>
<td>1.9</td>
<td>0.95</td>
</tr>
<tr>
<td>1.15</td>
<td>2.4</td>
<td>1.20</td>
</tr>
<tr>
<td>1.65</td>
<td>3.0</td>
<td>1.50</td>
</tr>
<tr>
<td>2.15</td>
<td>3.3</td>
<td>1.65</td>
</tr>
</tbody>
</table>

HydroCon pipes are easily cleaned with high pressure hosing and eduction equipment. Cleaning restores permeability of the pipes to near new condition.
3. Why use HydroCon pipes?

Stormwater treatment systems incorporating HydroCon pipes are used to:

- improve urban runoff water quality;
- infiltrate stormwater and protect groundwater and aquifers from pollution;
- harvest stormwater for non-potable purposes when using a 'confined' or lined system (i.e. where a system is contained within a water proof liner or membrane).

Importantly, HydroCon pipes can be used to deliver stormwater to bioretention systems, directly and underground, to prevent clogging and extend life cycle performance:

- allowing effective distribution of water around a bioretention system enabling large bioretention systems to be built that are capable of treating larger end of line flows. Without the use of HydroCon pipes water cannot be distributed easily across a bioretention system and this limits their potential size and application to small catchments;
- helping prevent filter media from becoming clogged with sediment. By removing a large proportion of sediment in the pipes before water reaches the bioretention system service life can be prolonged significantly;
- providing a way of filtering stormwater while leaving the surface above accessible for recreation activity. Mirvac’s award winning Ashgrove residential estate in Sydney (featured below) demonstrates the accessibility provided by a HydroCon pipe bioretention system with grassed surface. By contrast, bioretention systems, which are heavily vegetated with native plants, restrict areas for recreation and other land uses.
4. Where to use or not use HydroCon pipes

1. Site gradient

A minimum fall or hydraulic gradient is required across any site to treat the flow in a GPT or litter basket, prior to the flow entering the HydroCon pipe system.

HydroCon pipes can be used across all slopes if infiltration is possible and permitted.

On steeply sloping sites with sandy soils, which would otherwise be good sites for infiltration, many local government councils do not allow infiltration due to the potential for downstream seepage and ground instability. Geotechnical engineering advice should be sought prior to commencing design of an infiltration system on steeply sloping sites.

Lined or ‘confined’ systems can be considered where site gradients are greater than 2% and have sufficient hydraulic gradient for subsoil drainage collection. Very flat sites often do not have sufficient hydraulic fall to enable HydroCon pipe lined systems to be used. These sites may be better suited to HydroSTON permeable paving.

HydroSTON permeable concrete pavers can be used as surface cover in combination with HydroCon pipes where gradients are less than 8%.

Where gradients are less than 2%, lined HydroSTON pavement systems may be a more suitable option to lined HydroCon pipe systems.

2. Soil type

Soils most suitable for infiltration comprise loamy sand and sand having a $K_{\text{sat}}$ greater than 120 mm/hr.

When infiltration is proposed on loams, silty soils and light clays having a $K_{\text{sat}}$ of between 20 mm/hour and 120 mm/hour, it is important that infiltration trenches drain within 24 hours.

3. Groundwater

For most applications, the groundwater table should be a minimum of 0.5 m below the bottom of the trench of both lined and unlined systems.

4. Pipe Cover

Typically HydroCon pipes should be embedded at a minimum cover depth of 440 mm (from the surface to pipe obvert) with 1,000 mm from the surface to pipe invert (see Figures 1 & 2).

System options for different site gradients and soil types are summarized on the following page.
### System options for different site gradients and soil types

<table>
<thead>
<tr>
<th>Soil type\site gradient</th>
<th>0% to 2%</th>
<th>2% to 8%</th>
<th>8% &gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loamy sand, sands, coarse sands etc</td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>(K_{\text{sat}}&gt; 120\ \text{mm/hour})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater table must be min 0.5m below trench for unconfined systems</td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Loams, silty soils, light clays</td>
<td><img src="image7" alt="Image" /></td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
</tr>
<tr>
<td>(K_{\text{sat}} = 20\ \text{to} \ 120\ \text{mm/hour})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater table must be min 0.5m below trench. Recommended max trench drainage time = 24 hours</td>
<td><img src="image10" alt="Image" /></td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
<tr>
<td>Clay</td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
</tr>
<tr>
<td>(K_{\text{sat}} &lt; 20\ \text{mm/hour})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Icons shown represent the following systems:**

- **HydroCon permeable pipe - unlined system.** Soils allow infiltration.
- **HydroCon permeable pipe - lined (confined) system.** Subsoil drainage essential, option for water harvesting.
- **HydroSTON permeable pavers – unlined system.** Soils allow infiltration.
- **HydroSTON permeable pavers – lined (confined) system.** Subsoil drainage essential, option for water harvesting.
5. HydroCon pipe installations and configurations

HydroCon pipes have been used for many different applications, including drainage and street ponding, stormwater harvesting, stormwater retention/detention, aquifer recharge, bioretention and other water quality systems. Pipes are generally laid as single or double pipelines but can be configured in other arrangements appropriate to site constraints. The minimum number of pipes recommended for an installation should not be less than 3.

Drainage & street ponding, infiltration and aquifer recharge
Where subgrade properties are favourable for infiltration, HydroCon pipes can be used to infiltrate stormwater directly into the subgrade. For example, Rockdale Council (NSW), whose area covers much of the Botany Aquifer, has used HydroCon pipes in a variety of ways to cost effectively manage stormwater in existing residential areas. Port Stephens Council (NSW) approved the use of HydroCon pipes for a light industrial development at Heatherbrae, which is located over the Tomago Aquifer, a major source of drinking water for the City of Newcastle.

Stormwater harvesting
HydroCon pipe systems have been used to treat and harvest stormwater for irrigation, reducing/eliminating the need for draw on potable water supplies. City of Canada Bay Council (NSW) installed an extensive HydroCon pipe and pit system (shown below) to harvest water from the Powells Creek carpark for use on adjacent playing fields, while Kiama Council (NSW) – see Worked Example 1 - installed the first HydroCon pipe system in NSW to treat and harvest stormwater for non-potable purposes.
Retention/Detention
Camden Grove Estate at Grasmere (NSW) was the first residential estate to use HydroCon pipe systems to treat stormwater prior to storage in ponds within a drainage reserve.

Improve water quality
While all HydroCon pipe systems serve to improve water quality, HydroCon pipes are being specified to protect sensitive ecosystems. Manly Council (NSW) installed a HydroCon pipe system at Tania Park, Balgowlah to improve the quantity and quality of stormwater flows from Tania Park to Crater Cove National Park. With limited space available, Council was able to show that HydroCon pipes and underground filtration is a viable option for treating stormwater to a high quality appropriate for discharge to sensitive waterways or non-potable use.

Kiama Council required the installation of a HydroCon pipe system in a small residential development at Gerringong Headland to prevent stormwater runoff contamination of popular Werri Beach situated below the development. The system is an excellent example of the use of HydroCon pipes in conjunction with separate gravel and sand filter layers as water quality treatment measures.

HydroCon pipes have been specified by the Road Traffic Authority (RTA) of NSW to treat road runoff from the proposed upgrade of the Pacific Highway from Ballina to Ewingsdale in order to protect sensitive local environments.
Bioretention
As highlighted in this document, HydroCon pipes are increasingly being specified in improve the performance of bioretention systems. The WSUD system incorporating HydroCon pipes at the Ashgrove residential estate, Regents Park – featured on page 4 above – resulted in several prestigious awards for the developer, Mirvac Homes.

At Heritage Park Subdivision, Castle Hill (NSW), stormwater runoff is managed and treated at the site primarily with HydroCon pipe systems. In addition to enhanced water quality control, the system provides large storage volumes for on-site detention of stormwater. Such systems are a cost effective and sustainable alternative to traditional drainage systems because they allow for infiltration, volume and frequency control.

Industrial and other uses
Several HydroCon pipe systems, designed to treat runoff from industrial areas, have been installed at Weathertex and the Kinross Business & Industrial Park, Heatherbrae (NSW), and in transport depots at Mackay (QLD). Hobsons Bay Council (VIC) have installed a long HydroCon pipeline parallel to the beach at Altona to infiltrate stormwater directly into the sand rather than discharging onto the beach.
6. How do HydroCon pipes improve water quality?

HydroCon permeable concrete pipes allow water to be treated through a number of mechanisms. Essentially, the alkaline composition of the pipes affects the pH of the more naturally acidic stormwater, changing the solubility of heavy metals which then precipitate out of solution. Iron oxide is added to the pipes during manufacture to facilitate this process. The additive also gives HydroCon pipes their distinctive red appearance. Fine sediment falls out of solution in the very low velocity pipeline environment. Sediments accumulate on the base and walls of the pipes. Phosphorus and heavy metals particles bind strongly with sediments, while soluble phosphorus is adsorbed by the pipe matrix as water flows through the walls of the pipes.

Removal of nitrogen, however, involves biological processes. While particulate forms of nitrogen may be trapped temporarily inside the pipes, eventually they will decay releasing dissolved forms of nitrogen. Removal of nitrogen will then occur in the filter media surrounding the pipes.

The bottom of each pipe is sealed to enable settled sediments to be easily removed during periodic maintenance.

Research in Australia has reinforced previous research findings in Germany. While there has been extensive research in Germany on the performance of HydroCon pipe systems, the findings relate to systems as a whole, not to the performance of the pipes per se. Removal efficiencies for phosphorus and heavy metals of combined HydroCon pipe and media filtration systems were found to be between 90% and 98%.

Removal rates of zinc and copper have been shown to be very high in research conducted by the University of Munster and by Dunphy (2007) on several HydroCon pipe installations in NSW. Liebman et al (2009) found that it was likely that HydroCon pipes together with sand filtration removed total and dissolved zinc and copper providing very high levels of protection to ecosystems.

In 2010, Manly Hydraulics Laboratory was commissioned to test the performance of HydroCon’s HydroFilter device. Test results showed that the device’s permeable concrete filter removed on average 62% of Total Suspended Solids (TSS) and 75% of Total Phosphorus (TP). In the absence of data on the removal efficiencies of HydroCon pipes alone, the results provide a conservative base for the performance of the pipes in respect to TSS and TP.

Though not important in the German context, removal of nitrogen in stormwater has become a requirement in Australia. HydroCon pipes do not facilitate nitrification or denitrification and do not reduce Total Nitrogen (TN). Arguably, the only way to reduce TN is by filtering stormwater through a filter media (such as sand), which facilitates nitrification and denitrification and thus reduces the TN load. Work by Jonasson (2010) and Hatt (2007) throws useful light on the treatment performance of different filter media.
When TN removal is a treatment requirement, HydroCon pipes should be embedded in a filter media (sand or loamy sand) that is capable of removing nitrogen. Because nitrogen removing filter media will also remove TSS and TP, it is not necessary to separately account for the water quality benefit of HydroCon pipes in a water quality model such as MUSIC.

**HydroCon pipes improve water quality by removing sediment, TP and heavy metals. They do not remove or reduce TN. A surrounding filter media is required to reduce TN.**

If MUSIC modeling is required to prove how well a proposed system incorporating HydroCon pipes will perform, the user can opt to include the pipes in the water quality model while being aware that inclusion may not improve the total system performance significantly. As noted above, this is because the surrounding filter media will also remove TSS, TP and heavy metals.

### 7. Modelling HydroCon pipe systems in MUSIC

In most cases, inclusion of HydroCon pipes in a water quality model such as MUSIC will not show significant water quality benefits. However, inclusion of the pipes may assist in reducing and optimising the size of stormwater treatment system components, especially where TP or TSS removal governs the design of the system or device.

HydroCon pipes are always part of a treatment train. In MUSIC, a HydroCon pipe treatment train involves:

- a gross pollutant trap (GPT) to remove coarse sediment and gross pollutants, which could block the inner surface of the pipes – gross pollutant trap treatment node;
- HydroCon pipes themselves (generic treatment node);
- either a bioretention treatment node if the system is vegetated or a filtration media treatment node if not.

![Diagram of HydroCon system in MUSIC](image)

MUSIC requires the user to model the treatment train at hand in the order in which the components occur.

The user should refer to the MUSIC Toolkit for guidance on modeling the GPT, bioretention and filtration media treatment nodes.
It is essential to pretreat all stormwater flows prior to entry into the HydroCon pipe system. This is to prevent coarse sediment and debris hindering the flow of water through the HydroCon pipe wall early in the maintenance cycle. While sediment will not harm the pipes and can be removed when the pipes are cleaned, it is more cost effective to remove sediments from a GPT or litter basket.

Despite having a GPT upstream, some sediments, particularly finer sediments, will be deposited over time on the walls and base of the pipes.

Where treatable flow rates are relatively low, HydroCon’s HydroFilter® stormwater filter, which is licensed to Humes Water Solutions, may be suitable as a pretreatment device. However, where higher treatable flow rates are required, proprietary GPTs and litter baskets are generally specified.

Procedures for determining the minimum number of HydroCon pipes required and sizing of bioretention and filter media systems are detailed in Worked Examples 1 & 2 at the end of this document.

When specifying filter media depth in a bioretention or filter media node in MUSIC the following is recommended:

1. Where less than 50% of the average annual volume of runoff is treated by the HydroCon pipes (refer to Worked Example 1 for determination) the filter depth should equal the full depth of the proposed filter media. This approach is considered valid as the majority of the flow will be entering the filter media via surface infiltration.

2. Where more than 50% of the average annual volume of runoff is treated by the HydroCon pipes, the filter depth should be equal to the distance from the centre of the HydroCon pipe to the base of the filter media (in Worked Example 2 this is 550 mm). This approach is considered valid as the majority of the flow will be entering the filter media via the HydroCon pipes.

The user is advised to check sensitivity of results to filter depth variation.

**8. Use of HydroCon pipes in bioretention and media filtration systems**

HydroCon pipes can be used in many different situations as evident by the range of applications and projects on the HydroCon website. However, all stormwater management systems that incorporate HydroCon pipes embed the pipes in filter media.

Stormwater management systems that use filter media are usually associated with bioretention systems. The latter are defined by the vegetation (either native plants or grass) used as ground cover over a soil or sand-based filtration medium to remove particulates and soluble contaminants. They were developed partly because traditional surface loaded sand filters, constructed without vegetative cover, tended to dry out and develop crusted surfaces. To maintain hydraulic conductivity, crusted surfaces required regular breaking up. Bioretention systems may be lined or unlined and may or may not have an outlet pipe (underdrain).

Media filtration systems on the other hand, when used in stormwater management, have no vegetative cover, surfaces consisting generally of gravel, sand or other fine granular material. They are assumed always to have underdrains.
Research by the Facility for Advancing Water Biofiltration (FAWB) at Monash University (now integrated into the Centre for Water Sensitive Cities) found that vegetation helps to maintain hydraulic conductivity and plays an important role in neutralizing pollutants. However, more recent FAWB research has found that bioretention systems can be difficult to design, specify and construct and, if not done correctly, can leach TP and TN. This latest finding is now incorporated in MUSIC Version 4.

**The use of HydroCon pipes can overcome various concerns about vegetated bioretention systems. By delivering water underground to a bioretention or media filtration system, HydroCon pipes provide a maintainable interface between the filter media and stormwater, which prevents crusting and substantially reduces clogging.**

It can be argued that a media filtration system constructed using coarse sand of appropriate grading (see Table 2) with a rock mulch or grass for surface cover can deliver significantly improved stormwater quality without the risk of leaching. HydroCon pipes play a critical role in maintaining permeability and obviate the need for vegetative cover.

**Table 2: Filter media grading – coarse sand**

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>% passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75</td>
<td>100</td>
</tr>
<tr>
<td>2.36</td>
<td>100</td>
</tr>
<tr>
<td>1.18</td>
<td>95</td>
</tr>
<tr>
<td>0.60</td>
<td>56</td>
</tr>
<tr>
<td>0.30</td>
<td>12</td>
</tr>
<tr>
<td>0.15</td>
<td>3</td>
</tr>
<tr>
<td>0.075</td>
<td>2</td>
</tr>
<tr>
<td>&gt;0.075</td>
<td>1</td>
</tr>
</tbody>
</table>

Two approaches to filter media are shown below. The first approach (Figure 1), which was used for a HydroCon pipe system in 2004, involves filter media separated from the drainage layer by geotextile. The other approach (Figure 2) is based on Stormwater Biofiltration Adoption Guidelines (FAWB, 2009). The two approaches to filter media are shown in drawings associated with Worked Examples 1 & 2 respectively.

FAWB (2009) Guidelines adopt a layered filter media structure, maintaining that geotextiles are prone to blocking/clogging. Australian Runoff Quality (ARQ) 2006, however, states (Clause 10.5 b) that: “A geotextile may be used in place of the sand transition layer, but careful consideration needs to be given to avoiding clogging, by selecting an appropriate weave size (0.7 – 1.0 mm to match typical sand particles), and protecting the bioretention system during construction.”

Systems incorporating HydroCon pipes, such as the Kiama bioretention system, provide convincing evidence that a well designed system that uses a sand filter media graded as in Table 2 (see also grading table in Drawing Pipe-001 on page 16) and a needle punched non-woven geotextile to separate the filter media from the drainage layer is unlikely to clog under typical conditions.

Clogging may occur, however, if loamy or fine sand or a filter media with a high proportion of fines is used with a geotextile.

**Specification of the right type of filter media is critical to the performance of bioretention or media filtration systems.**
Figure 1: Typical HydroCon pipe embedment detail when using sand media and non woven geotextile to separate filter media and drainage layer

For additional information refer to Drawing Pipe-001 on page 16. For media filtration systems, replace topsoil and turf with a suitable gravel mulch.

Figure 2: Typical HydroCon pipe embedment detail when constructing a layered filter media in accordance with FAWB (2009) Biofiltration Adoption Guidelines

For additional information refer to Drawing Pipe-002 on page 22. For media filtration systems, there would be no vegetation cover.
9. Backwater effects on GPT & pipe network

If a GPT, such as a CDS unit, is to be used upstream to prefilter flows before entry into a HydroCon pipe system, the effects of backwater should be taken into account. Backflow can be caused by water ponding above the filter media and may have an effect on either a GPT or the upstream pipe system.

Most GPTs have a bypass feature, which is activated by both flow rate and backwater effects. A pipe network may experience backflow unless the system is off line with a dedicated high flow bypass line in place.

When a GPT’s design treatable flow rate is exceeded, its bypass system is activated and bypass flows will not be treated. Because HydroCon pipe systems are terminating systems, backwater effects may arise if there is insufficient head difference between the GPT and the pipes. This may force the GPT into premature bypass, causing sediment to accumulate rapidly inside the HydroCon pipes instead of the GPT.

Typically GPTs treat up to the 3 month flow rate, which is considerably larger than the minimum flow (see worked examples below) that the pipes are designed to exfiltrate.

Ideally the GPT outlet level should be located as far above the surface level of the filter media as possible and preferably above the maximum storage level. Where low head is a problem, litter baskets could be used instead of GPTs to reduce head requirements.

Computer models such as DRAINS are useful for checking the hydraulic performance of systems.

**Designers must ensure that the HydroCon pipes do not interfere hydraulically with the functioning of the GPT and overall pipe network.**

10. Worked Examples

There are 2 worked examples:

**Worked Example 1 shows how to:**
- determine the minimum number of pipes needed to maintain a healthy surface above the filter.

**Worked Example 2 shows how to:**
- model a system to treat a particular percentage of water – 95% is adopted as a treatment target in this example.
- work out the water quality performance of HydroCon pipes.
10.1 Worked Example 1 - Bioretention system with surface detention

Background:
- Based on a 2004 retrofit project shown below in Plates 1 to 3 and Drawing Pipe 001.
- Located at Kiama NSW in a busy park next to the CBD.
- Council stipulated that there was to be no loss of effective parkland due to a wetland or other device.
- Design involved “sculpting” a depression into the parkland to create surface storage.
- The water quality performance of this system was measured by Dunphy. Her research found that the system retained about 40% of TN, 65% of TP and 75% of TSS. It might be noted that a recent MUSIC V4 model of this system predicted the same TP and TN performance with a TSS performance 3.5% higher.
- Example shows a grass covered bioretention system where grass maintains the porosity of the filter media.
- Litter baskets were placed in surface inlet pits in the catchment to trap gross pollutants.

Drawing Pipe-001

PLATE 1:
Kiama system under construction in 2004 showing HydroCon pipes being installed. The pipes are configured in an H shape with two surcharge pits to distribute surcharged water more evenly across the filter surface.

Subsoil flushing points can be seen raised above the surrounding sand. Geotextile has been placed around and underneath the filter media to stop filter media migrating into the drainage layer.

Low flows pass through the HydroCon pipes and into the surrounding sand filter. High flows surcharge up above the filter and are stored on the surface before percolating down through the grass and filter media.

PLATE 2:
Completed sand filter system.

The image (February 2011) shows a high quality well drained accessible surface. Both surcharge pits are visible in the image. Overflow pit is located off the image to the right.

**HydroCon pipe systems are ideal for retrofitting into existing parks as well as integrating into new ones.**

PLATE 3:
System with the surface storage full and likely to be discharging into overflow pit during height of a torrential storm on 21 March 2011.

Treated flows are collected in a subsoil manifold for future use. Water storage tanks are located underground.
Step 1  Determine Design Objectives

Design either:

• a system with the minimum number of pipes – such systems are characterised by the availability of surface storage; or
• a system which does not rely on extensive surface storage – see Worked Example 2.

Step 2  Establish a Music Model

• Construct a MUSIC model with a single Urban Catchment source node.
• Use of 6 minute rainfall is essential when sizing HydroCon pipes.

Step 3  Determine Catchment Areas

Model ONLY the impervious fraction of the catchment.

The catchment in this example is 8.33 Ha and 60% impervious ie. 5 Ha of 100% impervious area.

If a catchment is modelled with pervious areas included, the minimum number of pipes may be underestimated.
Step 4 Run the Model

Step 5 Set Flow-based Sub-Sample Lower Flow Threshold to 0.00001 m$^3$/s
This is done to ensure that only periods of flow are examined and that dry periods are excluded.

> Right click on the node, then
> Flow-Based Sub-Sample Bounds
> Enter data as shown
> Lower Flow Threshold is sensitive – do not alter

Step 6 Determine the Mean Flow

> Right click on the catchment node again, then
> Statistics, then
> Flow Based Sub-Sample, then
> Read off the Mean Flow value
Step 7 Determine the minimum number of pipes required

Use Equation 1 to determine the minimum number of pipes required.

**EQUATION 1**

\[
\text{Length of HydroCon pipe in metres} = \frac{0.5 \times \text{Mean Flow (L/s)}}{\text{Impeded minimum exfiltration rate (L/s/m)}}
\]

A pressure head of 0.15 m is recommended for calculating the number of pipes required. This means (from Table 1) that the recommended impeded minimum exfiltration rate will be 0.6 l/s/m of pipe.

Inserting the 0.5 x Mean Flow value (l/s) and recommended impeded minimum exfiltration rate (l/s/m) into Equation 1:

\[
\text{Length of HydroCon pipe in metres} = \frac{0.5 \times 38.6}{0.6} = 32.167 \text{ ie. 32 pipes}
\]

The system will therefore require 32 metres of HydroCon pipe (32 x 1 m lengths) to exfiltrate at a rate of 32 x 0.6 = 19.2 l/s.

In other words, a minimum of 32 m of HydroCon pipes are required to ensure that the proposed filter functions so that a high quality surface is maintained.
Sizing the bioretention system

To work out the size of the bioretention system in which to embed the 32 m of HydroCon pipes, follow procedures in the MUSIC Toolkit for sizing a bioretention system.

To meet water quality targets and achieve best practice, vary the size of the surface storage area and depth, filter media area, depth and physical structure to suit site constraints.

Since much less than mean flow is treated in this case, filter depth in the filter media can be set equal to the full depth of the filter media.

Notes on hydraulic operations

• In Drawing Pipe-001, Pit A is configured so that the off-take pipe invert level is set at RL 5.95 which is below the existing stormwater line at RL6.72. This means that most flows will be diverted into the bioretention system for treatment because there is a 77 cm drop in Pit A.

• Pit A is also configured to make the system an off line system with overflow of the basin at a level lower than the main stormwater line invert level. This prevents any backwater effects.

• Pits B and C are surcharge pits set at RL6.0 and with sumps to allow eduction of water during cleaning. Note that deep sumps tend to accumulate sediment naturally.

• Pit D is an overflow pit set at RL 6.66. The invert level of the main stormwater line is RL 6.72. This means that the system will overflow before it goes into bypass at the main stormwater line and maximizes the volume of water that can be treated in the bioretention system while providing safe passage of all overflows.

• Generally subsoil drainage will not limit the outflow from a bioretention system, but it might do so and should be checked. Rates of inflow into subsoil drainage pipes can be based on the orifice equation. If necessary, information and guidance should be sought from subsoil drainage pipe manufacturers.
10.2 Worked Example 2 - A system with limited surface storage

Worked Example 2 is set in the City of Melbourne and involves a hypothetical commercial development with a new car park.

Background:
- A suitable climate file containing 6 minute rainfall for Melbourne City was downloaded from Melbourne Water’s website.
- The catchment area is 3,750 m² and assumed to be 100% impervious.
- The proposed design is shown in Drawing Pipe-002.
- Extended detention or surface storage is limited to 100mm. In some cases it can be zero.
- Pretreatment consists of 200 micron litter baskets in all surface inlet pits within the catchment.

This example shows:
- How to work out the number of pipes required to treat 95% of the annual average volume of runoff.
- How to use MUSIC to model the water quality performance of the pipes.

Determining the minimum number of HydroCon pipes required to treat 95% of the flow

Determining the number of pipes required to treat the 95% flow rate is an iterative procedure which needs a starting point. That starting point can be based on Steps 1 to 7 shown in Worked Example 1.

Step 1 Determine the minimum number of pipes required

Follow Steps 1 to 7 in Worked Example 1. Rework step 7 as follows:

EQUATION 1

\[
\text{Length of HydroCon pipe in metres} = \frac{0.5 \times \text{Mean Flow (L/s)}}{\text{Impeded minimum exfiltration rate (L/s/m)}}
\]

Inserting the 0.5 x Mean Flow value (l/s) and recommended impeded minimum exfiltration rate (l/s/m) into Equation 1:

\[
\text{Length of HydroCon pipe in metres} = \frac{0.5 \times 1.71 \text{ (l/s)}}{0.6} = 1.4 \text{ i.e. 2 pipes}
\]

Commence the iterative procedure assuming a minimum of 2 pipes. This is likely to be well below the number of pipes required to treat 95% of the volume of flow.

Step 2 Add a GPT & a Generic Node

> Add a Gross Pollutant Trap and a Generic Node (HydroCon Pipes) to the model.
> Inclusion of a GPT is strongly recommended to trap coarse sediment prior to the HydroCon pipe. To configure the GPT Node in this Guideline – refer to MUSIC for further details.
**Step 3 Set the High Flow By-pass**

> Set the High Flow By-pass using the number of pipes and Equation 2.

**EQUATION 2**

Exfiltration rate from the pipes (l/s) = Impeded minimum exfiltration rate (l/s/m) x number of pipes (m)

Adopt 0.6 l/s for the impeded minimum exfiltration rate.

Iteration has commenced with 2 HydroCon pipes (Step 1):
The exfiltration rate from 2 pipes = 0.6 x 2 = 1.4 l/s.

In Inlet Properties enter a High Flow By-pass equal to the flow rate that can be exfiltrated by the pipe. From Equation 2:
The model limits flows to the nearest 1 l/s.
Step 4  Run the Model

Step 5  See how much water 2 HydroCon pipes will treat

> Statistics, then
> Node Water Balance

![Node Water Balance - HydroCon Pipes](image)

**EQUATION 3**

\[
\text{Volume of water treated by pipes} = \frac{\text{Transfer Function Out (ML/yr)}}{\text{Flow In (ML/yr)}}
\]

Volume of water treated by 2 HydroCon pipes = \(0.793/2.050 = 38.7\%\).
**Step 6  Iterate until target is reached**

> Adjust the High Flow By-pass upward and rerun the model.

> Check the % of water treated and repeat until 95% of the water is treated.

After several iterations, a high flow By-pass rate of 12 l/s gives the results shown in the above Water Balance table ie 1.944/2.050 indicates 95% of flows will be treated.

From Equation 2, the number of pipes required for an exfiltration rate of 12 l/s is: 12/0.6 = 20 pipes.

In summary, 20 HydroCon pipes are required to treat 95% of the average annual volume of runoff from a 3,750m² car park in Melbourne.
Modelling Water Quality: How to configure the HydroCon Pipes Generic Node

Continuing on with Worked Example 2, the following section shows how to model the water quality performance of HydroCon pipes.

**Step 1 Adjust High Flow By-pass**

In Properties of HydroCon pipes, click on the flow radio button:

> Set Low Flow By-pass at 0.00 (usual default setting).
> The High Flow By-pass value is set at 12 l/s or 0.012 m$^3$/s i.e. 20 pipes.

**Flow**

- Input and output values should not be changed.
- The effect on flows of pipe storage volumes is ignored.
Step 2 Adjust the TSS Transfer Function

**Total Suspended Solids (TSS)**

> Hover over the point at coordinates (1000,1000).
> Right click over this point – an Edit Point window will appear.
> Enter input value as 1000 mg/L.
> Enter output value as 380 mg/L. This value is based on performance tests conducted on HydroCon porous concrete filters by Manly Hydraulics Laboratory in 2010, where average retention rates for TSS were found to be 62%. Output value in this case is 38% of input value i.e 380 mg/L. 62% is very conservative with field tests showing up to 80% TSS removal.
Step 3 Adjust the TP Transfer Function

Total Phosphorus (TP)

> Enter input value as 10.0 mg/L in Edit Point.
> Enter output value as 2.5 mg/L. This value is based on performance tests conducted on HydroCon porous concrete filters by Manly Hydraulics Laboratory in 2010, where average retention rates for TP were found to be 75%. Output value in this case is 25% of the input value i.e. 2.5 mg/L.
Step 4  Adjust the Gross Pollutants Transfer Function

Gross Pollutants

• Since gross pollutants cannot pass through the walls of HydroCon pipes, 100% of treated flows are removed.

> Enter the input and output values for the single point, with output value at 0.

Step 5  Run the Model
Step 6  Review Results

> Statistics, then
> Mean Annual Loads

The results above show that the HydroCon pipes, which have been sized to treat 95% of the average annual flow, retain about 60% of TSS and 70% of TP.

Sizing the bioretention system

The minimum size of the bioretention system or media filtration system required to meet water quality objectives can be determined by incrementally increasing filter and detention areas until the water quality objective is satisfied. This process is not shown here – the user is referred to MUSIC for more information on sizing bioretention nodes.

Note that in this example 95% of the runoff is treated inside the pipes. Therefore, when modeling the filter depth in the bioretention node, this must be limited to the depth from the centre of the pipe to the base of the filter, which is 550 mm in this case.
11. References


MUSIC by eWater: Toolkit (www.toolkit.net.au/music)

Other relevant publications -
see HydroCon website www.hydrocon.com.au/research-publications in particular:


