GUIDELINE SPECIFICATIONS FOR SOIL MEDIA IN BIORETENTION SYSTEMS

The following guideline specifications for soil media in bioretention systems have been prepared on behalf of the Facility for Advancing Water Biofiltration (FAWB) to assist in the development of bioretention systems, including the planning, design, construction and operation of those systems.

The guideline specifications are in two parts:

- Soil Media Specifications for Bioretention Systems with a Range of Vegetation Types
- Soil Media Specifications for Tree Pod Bioretention Applications

1 SOIL MEDIA SPECIFICATIONS FOR BIORETENTION SYSTEMS WITH A RANGE OF VEGETATION TYPES

1.1 Bioretention Systems with Imported Media

The bioretention soil media specifications require three layers of media. Filter media (600mm deep or as specified in the engineering design), a transition layer (100mm deep) and a drainage layer (150mm deep).

1.1.1 Filter Media - General Description

The material can be of siliceous or calcareous origin. Only, minimal light compaction to avoid subsidence and uneven drainage should be carried out. The bioretention system will operate so that water will infiltrate into the filter media and move vertically down through the profile. The prescribed hydraulic conductivity will generally be between 50-300mm/hr.

Maintaining the prescribed hydraulic conductivity is crucial. Permeability testing using the Australian Standard (AS4419-2003 Appendix H) method will generally be suitable for determining the hydraulic conductivity of a particular soil. However, in some circumstances, additional hydraulic conductivity testing will be required (see below for further details).

The media is required to support a range of vegetation types (from groundcovers to trees) that are adapted to freely draining soils with occasional flooding.

In general the media should be a sandy loam to loamy sand soil with an appropriately high permeability under compaction and should be free of rubbish and deleterious material. The soils should contain some organic matter for increased water holding capacity but be low in nutrient content. In general appropriate material is likely to be approximated by a mix of 80-90% sand, 10-20% loam soil and 3-10% composted organics or peat. A detailed specification for filter media is described below.

1.1.2 Filter Media - Testing Requirements

To determine whether a soil is suitable the following tests should be undertaken:

1. Particle size distribution (PSD)
2. AS4419-2003 - Soils for landscaping and garden use (specification for natural soil or soil blend unless stated above)
3. Water Holding Capacity - *required where PSD does not meet specifications but silt + clay is <12% or in regions likely to experience extended dry spells*
4. Saturated Hydraulic Conductivity - *required where PSD does not meet specifications*

Information from suppliers

In some cases, suppliers may have PSD and AS4419-2003 testing results available for various soils. If the testing was carried out on the batch of soil available for purchase these results should be adequate. (Additional hydraulic conductivity and water holding capacity testing may still be required).

Soils that do not meet PSD

Soils that do not lie within the specified PSD may be suitable if the silt plus clay content is less than 12% and it meets the specifications for the following tests:

1. AS4419-2003
2. Additional Hydraulic Conductivity Testing (e.g. McIntyre and Jakobsen (1998) method)
3. Water Holding Capacity

1.1.3 Filter Media - Detailed Specifications

Detailed specifications (compiled with assistance from Sydney Environmental and Soil Laboratory, March 2006) are listed below. Testing requirements to confirm the suitability of a soil will vary depending on the information provided by the supplier and the quantity of soil required (see 'testing requirements below).

1. Particle Size Distribution

Soils with infiltration rates in the appropriate range typically vary from sandy loams to loamy sands. Soils with the following composition (percentage range w/w) are likely to have an infiltration rate in the appropriate range and have suitable structural integrity (adapted from United States Golf Association: Method of Putting Green Construction, 1993)-

Clay	2-4%	(<0.002 mm)
Silt	4-8%	(0.002-0.05 mm)
Very Fine Sand	5-10%	(0.05-0.15 mm)
Fine Sand	10-25%	(0.15-0.25 mm)
Medium to Coarse Sand	60-70%	(0.25-1.0 mm)
Coarse Sand	7-10%	(1.0-2.0 mm)
Fine Gravel	<3%	(2.0-3.4 mm)

Variation in large particle sizes is flexible (i.e. an approved material does not have to be screened). However, the particle size distribution of the smaller particles (clay and silt) is a crucial element of the filter media specification. Where soils are prone to structural collapse the hydraulic conductivity may change dramatically depending on the state of collapse of the soil. However, ensuring the total clay and silt mix is less than 12% reduces the likelihood of structural collapse of such soils.

2. *AS4419- 2003 (Soils for Landscaping and Garden Use)*

   i. Bulk density – as specified for 'natural soils and soil blends' >0.7 kg/L

   ii. Organic Matter Content – **between 3 and 10% w/w** (For soils low in organic matter content the top layer (~300mm) of the filter media should be amended to meet the specified organic matter content (3 -10% w/w))

   iii. Wettability – as specified for 'natural soils and soil blends' >5 mm/min

   iv. pH – as specified for 'natural soils and soil blends' 5.5 – 7.5 (pH 1:5 in water).

   v. Electrical Conductivity (EC) – as specified for 'natural soils and soil blends' <1.2dS/m

   vi. Phosphorus – **<100mg/kg** – NOTE: Appropriate soils are likely to range from Siliceous Sands to Alluvial Soils and show little to no profile development. These soils generally have phosphorus concentrations in the range of 100 to 2000 mg/kg (Stace *et al*, 1968). Soils with phosphorus concentrations <100mg/kg are suitable for bioretention soil media. Soils with phosphorus concentration >100mg/kg should be tested for potential leaching. Where plants with moderate phosphorus sensitivity are to be used, phosphorus concentrations should be <20 mg/kg.

   vii. Nitrogen Drawdown (NDI) – as specified for 'natural soils and soil blends' >0.5 NDI_{150} (NDI assesses the ability of a soil to drawdown or immobilize soluble nitrogen).

   viii. Toxicity – as specified for 'natural soils and soil blends'

   ix. Dispersibility – as specified for 'natural soils and soil blends' Category 1 or 2

   x. Permeability – **hydraulic conductivity as specified in engineering design.** The prescribed hydraulic conductivity will generally be between 50-300mm/hr. A suitable soil will demonstrate a saturated hydraulic conductivity within ±20% of the hydraulic conductivity prescribed in the engineering designs.

   xi. Texture – sandy loam to loamy sand

   xii. Large particles – as specified for 'natural soils and soil blends'

3. *Additional Hydraulic Conductivity Testing – required where PSD does not meet specifications but silt + clay is <12%*

   Saturated hydraulic conductivity – as specified in engineering design. (Suitable methods include: McIntyre and Jakobsen (1998) method, AS/NZS 1547 permeability testing method).

4. *Water Holding Capacity – required where PSD does not meet specifications but silt + clay is <12% or in regions likely to experience extended dry spells*

   Water Holding Capacity- at least 15-20% by volume at 300mm of suction using the McIntyre and Jakobsen (1998) method.

Any component or soil found to contain high levels of salt, high levels of clay or silt particles (exceeding the particle size limits set above), extremely low levels of organic carbon or any other extremes which may be considered retardant to plant growth and denitrification should be rejected.

Testing requirements to determine suitable soils are described in Filter Media – Testing Requirements. It may be possible to 'construct' a suitable filter media by amending the local soils. A procedure for constructing a suitable filter media is outlined below.

1.1.4 Transition Layer – Detailed Specifications

Transition layer material shall be sand/ coarse sand material. An indicative particle size distribution is provided below:

% passing	1.4 mm	100 %
	1.0 mm	80 %
	0.7 mm	44 %
	0.5 mm	8.4 %

This grading is based on a Unimin 16/30 FG sand grading.

Geotextile fabrics are not recommended for use in bioretention systems due to the risk of clogging. An open knitted shade cloth can be placed between the transition layer and the drainage layer to help reduce the downward migration of smaller particles.

1.1.5 Drainage Layer – Detailed Specifications

The drainage layer is to be fine gravel, such as a 2-5 mm screenings.

1.2 Constructing Filter Media from In-situ Soils

1. Identify if local top soil is capable of supporting vegetation growth and if there is enough top soil (some top soils are very shallow) be used as a base for the filter media (may require active collection of top soil during the construction process). Any topsoil found to contain high levels of salt, extremely low levels of organic carbon (<<5%), or any other extremes which may be considered retardant to plant growth should be rejected. If the top soil is not suitable, a sandy loam soil can be purchased from a supplier for use as a base soil.
2. Conduct laboratory tests to establish hydraulic conductivity, water holding capacity, particle size distribution, and AS4419-2003 parameters.
3. If the soil needs to be amended to achieve the desired design saturated hydraulic conductivity and particle size distribution either mix in a loose non-angular sand (to increase saturated hydraulic conductivity) or a loose soft clay (to reduce saturated hydraulic conductivity).
4. The required content of sand or clay (by weight) to be mixed to the base soil will need to be established in the laboratory by incrementally increasing the content of sand or clay until the desired saturated hydraulic conductivity is achieved (within reasonable bounds). The sand or clay content (by weight) that achieves the desired hydraulic conductivity should then be adopted on-site.
5. The base soil should have sufficient organic content to establish vegetation on the surface of the bio-retention system. If the proportion of base soil in the final mix is less than 50% then it may be necessary to add in additional organic material. This will be limited to 10% organic content (measured in accordance with AS1289 4.1.1).
6. The pH of the soil mixture for the filtration layer is to be amended to between 5.5 and 7.5, before delivery to the site.
7. Ensure soil meets the specifications for:
    a. hydraulic conductivity,
    b. water holding capacity,
    c. particle size distribution, and
    d. AS4419-2003 parameters.

    as set out in the Section 1.1.3 – Filter Media Detailed Specifications.

1.3 Targeting Specific Pollutants

The media specification described above is designed for applications where the types and concentrations of pollutants are expected to be similar to 'normal' urban pollutant loads. In some cases, receiving waters may be more sensitive or target pollutants may differ (excessive heavy metals or increased nutrient concentrations for example). For sensitive sites or where the runoff is expected to have a composition that differs from general urban pollutant loads, media can be further amended to increase treatment efficiency.

For example, activated carbon (or another material with a high adsorption capacity) can be added where high concentrations of heavy metals are expected; the organic matter content of the media can be increased for sites where nitrogen is the target pollutant (and therefore denitrification is the target process); commercial products with high adsorption capacity that target specific pollutants such as phosphorus can also be added to the media where required.

2 SOIL MEDIA SPECIFICATIONS FOR TREE POD BIORETENTION APPLICATIONS

2.1 Bioretention Systems for trees

For trees, the hydraulic conductivity will generally be prescribed to be within the range of 30 – 100 mm/hr. Maintaining the prescribed hydraulic conductivity is crucial.

Where soils are prepared for trees the pH of the soil mixture is to be corrected to between 5.5 and 7.5, using dolomite, before delivery to the site.

The filter media of 'Tree Bioretention Pods' consists of two layers, the base layer and the surface layer. The difference between the layers is the organic content, as discussed below. The total depth of the filter media profiles for trees must be deep enough to provide tree stability

As in other bioretention applications, a transition layer and a drainage layer are also required.

2.1.1 Base Layer

The tree media base layer should meet the same specifications as described for bioretention filter media with exception to the Organic Matter Content which should be low. PSD and AS4419-2003 testing should be carried out and a suitable media will demonstrate the following characteristics:

1. *Particle Size Distribution*

   Soils with infiltration rates in the appropriate range typically vary from sandy loams to loamy sands. Soils with the following composition are likely to have an infiltration rate in the appropriate range and have suitable structural integrity –

Clay	2-4%	(<0.002 mm)
Silt	4-8%	(0.002-0.05 mm)
Very Fine Sand	5-10%	(0.05-0.15 mm)
Fine Sand	10-25%	(0.15-0.25 mm)
Medium to Coarse Sand	60-70%	(0.25-1.0 mm)
Coarse Sand	7-10%	(1.0-2.0 mm)
Fine Gravel	<3%	(2.0-3.4 mm)

   Variation in large particle sizes is flexible (i.e. an approved material does not have to be screened). However, the particle size distribution of the smaller particles (clay and silt) is a crucial element of the filter media specification. Where soils are prone to structural collapse the hydraulic conductivity may change dramatically depending on the state of collapse of the soil. However, ensuring the total clay and silt mix is less than 12% reduces the likelihood of structural collapse of such soils.

2. *AS4419- 2003 (Soils for Landscaping and Garden Use)*

   Bulk density – as specified for 'natural soils and soil blends' >0.7 kg/L

   Organic Matter Content – less than 3-5% w/w

   Wettability – as specified for 'natural soils and soil blends' >5 mm/min

   pH – as specified for 'natural soils and soil blends' 5.5 - 7.5 (pH 1:5 in water)

Electrical Conductivity (EC) – as specified for 'natural soils and soil blends' <1.2dS/m

Phosphorus – <100mg/kg – NOTE: Appropriate soils are likely to range from Siliceous Sands to Alluvial Soils and show little to no profile development. These soils generally have phosphorus concentrations in the range of 100 to 2000 mg/kg (Stace et al, 1968). Soils with phosphorus concentrations <100mg/kg are suitable for bioretention soil media. Soils with phosphorus concentration >100mg/kg should be tested for potential leaching. Where plants with moderate phosphorus sensitivity are to be used, phosphorus concentrations should be <20 mg/kg.

Nitrogen Drawdown (NDI) – as specified for 'natural soils and soil blends' >0.5 NDI_{150}

Toxicity – as specified for 'natural soils and soil blends'

Dispersibility – as specified for 'natural soils and soil blends' Category 1 or 2

Permeability – **hydraulic conductivity as specified in engineering design**

Texture – sandy loam to loamy sand

Large particles – as specified for 'natural soils and soil blends'

2.1.2 Surface Layer

The tree media surface layer is the top 150mm of soil (placed onto the base layer). The tree media surface layer should be the same as the base layer however further amended to include:

Organic matter at 10% by volume.

Suitable organic matter will be coco peat or fine compost. Any compost used should conform to the description of "composted soil conditioner" in Australian Standard AS 4454-1999.

2.1.3 Transition Layer

Transition layer material shall be sand/coarse sand material. An indicative particle size distribution is provided below:

% passing	1.4 mm 100 %
	1.0 mm 80 %
	0.7 mm 44 %
	0.5 mm 8.4 %

This grading is based on a Unimin 16/30 FG sand grading.

2.1.4 Drainage Layer

The drainage layer is to be fine gravel, such as a 2-5 mm screenings.

3 References

Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J. and Hallsworth, E.G. (1968) *A Handbook of Australian Soils*, Rellim Technical Publications for the CSRIO, South Australia.

Standards Australia (2003) *Australian Standard – Soils for landscaping and garden use*, Standards Australia International Ltd, Sydney.