uniform hydraulic conveyance, thus reducing the risk of short circuiting.

6.3.4.3 Macrophyte Zone Edge Design for Safety

The batter slopes on approaches and immediately under the permanent water level have to be configured with consideration of public safety (refer Figure 6.8). It is recommended that a gentle slope to the water edge and extending below the water line be adopted before the batter slope steepens into deeper areas.

![Figure 6.8: Example of Edge Design to a Constructed Wetland System](image)

The safety requirements for individual wetlands will vary from site to site and requires careful consideration. *Sediment Basin Design, Construction and Maintenance Guidelines* (BCC 2001) requires the following:

- For water depths greater than 150 mm and maximum batter slope of 5:1 (H:V) or less, no fencing is required.
- For water depths greater than 150 mm and maximum batter slope greater than 5:1 (H:V) fencing is required.

These requirements would equally apply to constructed wetland systems.

In some cases, vertical edges are used for wetlands (refer to Section 6.4). When vertical edges are used, a safety fencing/barrier should be considered on top of concrete or stone walls where:

- there is a risk of serious injury in the event of a fall (over 0.5 m high and too steep to comfortably walk up/down or the lower surface has sharp or jagged edges)
- there is a high pedestrian or vehicular exposure (on footpaths, near bikeways, near playing/sporting fields, near swings and playgrounds)
- where water ponds to a depth of greater than 300 mm on a constructed surface of concrete or stone
- where the water is expected to contain concentrated pollutants
- where mowed grassed areas abut the asset.

The type of fence/barrier to be considered should be a:

- pool fence when there is a chance of drowning or infection from the asset and the surrounding area is
specifically intended for use by small children (swings, playgrounds, sporting fields etc.)

- galvanised tubular handrail (in accordance with standard drawing UMS 241) without chain wire elsewhere
- dense vegetation (hedge) at least 2 m wide and 1.2 m high (minimum) may be suitable if vandalism is not a demonstrated concern.

6.3.4.4 Macrophyte Zone Soil Testing

Constructed wetlands are permanent water bodies and therefore the soils in the base must be capable of retaining water. Geotechnical investigations of the suitability of the in-situ soils are required to establish the water holding capacity of the soils. Where the infiltration rates are too high for permanent water retention, tilling and compaction of in-situ soils may be sufficient to create a suitable base for the wetland. Where in-situ soils are unsuitable for water retention, a compacted clay liner may be required (eg. 300 mm thick). Specialist geotechnical testing and advice must be sought.

6.3.5 Step 5: Design Macrophyte Zone Outlet

A macrophyte zone outlet has two purposes: (1) hydrologic control of the water level and flows in the macrophyte zone to achieve the design detention time; and (2) to allow the wetland permanent pool to be drained for maintenance.

6.3.5.1 Riser Outlet – Size and Location of Orifices

The riser outlet is designed to provide a uniform notional detention time in the macrophyte zone over the full range of the extended detention depths. The target maximum discharge \( Q_{\text{max riser}} \) may be computed as the ratio of the volume of the extended detention to the notional detention time as follows:

\[
Q_{\text{max riser}} = \frac{\text{extended detention storage volume (m}^3\text{)}}{\text{notional detention time (s)}}
\] \hspace{1cm} \text{Equation 6.1}

The placement of orifices along the riser and determining their appropriate diameters is an iterative process. The orifice equation (Equation 6.2) is applied over discrete depths along the length of the riser starting at the permanent pool level and extending up to the riser maximum extended detention depth. This can be performed with a spreadsheet as illustrated in the worked example in Section 6.7.

\[
A_0 = \frac{Q}{C_d \sqrt{2gh}} \quad \text{(Small orifice equation)}
\] \hspace{1cm} \text{Equation 6.2}

Where
- \( C_d \) = orifice discharge coefficient (0.6)
- \( h \) = depth of water above the centroid of the orifice (m)
- \( A_0 \) = orifice area (m\(^2\))
- \( Q \) = required flow rate to achieve notional detention time (m\(^3\)/s) at the given \( h \)
- \( g \) = 9.79 m/s\(^2\)

As the outlet orifices can be expected to be small, it is important that they are prevented from clogging by debris. Some form of debris guard is recommended as illustrated in Plates 5 - 7 below. An alternative to using a debris guard is to install a riser in a pit located in the embankment surrounding the wetland macrophyte zone (thus reducing any visual impact). A riser within the pit can also be configured with a weir.
plate (by drilling holes through the plate). An advantage of using a weir plate is that it provides an ability to drain the wetland simply by removing the weir plate entirely. Additionally, shorter weir plates may also be used during the vegetation establishment phase, thus providing more flexibility for water level manipulation.

The pit is connected to the permanent pool of the macrophyte zone via a submerged pipe culvert. The connection should be adequately sized such that there is minimal water level difference between the water within the pit and the water level in the macrophyte zone. With the water entering into the outlet pit being drawn from below the permanent pool level (i.e. pipe obvert a minimum 0.3 m below permanent pool level), floating debris is generally prevented from entering the outlet pit, while heavier debris would normally settle onto the bottom of the wetland. The riser pipe should be mounted upright on a socketed and flanged tee with the top of the pipe left open to allow overtopping of waters if any of the riser orifices become blocked. Figure 6.9 shows one possible configuration for a riser outlet pit.

6.3.5.2 Maintenance Drains

To allow access for maintenance, the wetland should have appropriate allowance for draining. A maintenance drainage pipe should be provided that connects the low points in the macrophyte zone bathymetry to the macrophyte zone outlet. A valve is provided on the maintenance drainage pipe (typically located in the outlet pit as shown in Figure 6.9), which can be
operated manually. The maintenance drainage pipe should be sized to draw down the permanent pool within 12 hours (i.e. overnight). If a weir plate is used as a riser outlet, provision should be made to remove the weir plate and allow drainage for maintenance.

6.3.5.3 Discharge Pipe

The discharge pipe of the wetland conveys the outflow of the macrophyte zone to the receiving waters (or existing drainage infrastructure). The conveyance capacity of the discharge pipe is to be sized to match the higher of the two discharges (i.e. maximum discharge from the riser or the maximum discharge from the maintenance drain).

6.3.6 Step 6: Design High Flow Bypass Channel

The bypass channel accepts ‘above design flow’ from the inlet zone of the wetland via the bypass weir (Section 6.3.3) and conveys these flows downstream around the macrophyte zone of the wetland. The bypass channel should be designed using standard methods (i.e. Manning’s Equation) to convey the ‘above design flow’ (Section 6.3.2) and to avoid bed and bank erosion (see Chapter 2). Typically, a turf finish will provide appropriate protection for most bypass channel applications (but velocities need to be checked). Plates 9 - 10 show typical high flow bypass channel configurations.

Plates 9 – 10: Constructed Wetland Bypass Weir and Channel Configurations

6.3.7 Step 7: Verification Checks

6.3.7.1 Macrophyte Zone Resuspension Protection

The principle pathway for biological uptake of soluble nutrients in wetlands is through biofilms (epiphytes) attached to the surface of the macrophyte vegetation. The biofilms, being mostly algae and bacteria, are susceptible to wash out under high flow conditions. Further, wetland surveys indicate that up to 90 % of the total nutrients are stored in the sediments, therefore, the key to effective retention of pollutants is managing high velocity flows that could potentially resuspend and remobilise these stored pollutants.

A velocity check is to be conducted for design conditions, when the wetland water level is at the top of the extended detention level and the riser is operating at design capacity, to ensure velocities are less than 0.05 m/s through all zones of the wetland. The following condition must be met:
Draft Water Sensitive Urban Design
Engineering Guidelines

Equation 6.3

\[
\frac{Q_{\text{max riser}}}{A_{\text{section}}} < 0.05 \text{m/s}
\]

Where

- \(Q_{\text{max riser}}\) = target maximum discharge (defined in equation 6.1) (m\(^3\)/s)
- \(A_{\text{section}}\) = wetland cross sectional area at narrowest point*, measured from top of extended detention (m\(^2\))

* minimum wetland cross-section is used when undertaking this velocity check

6.3.7.2 Confirm Treatment Performance

If the basic wetland parameters established by the conceptual design phase have changed during the course of undertaking detailed design (e.g. macrophyte zone area, extended detention depth, etc.) then the designer should verify that the current design meets the required water quality improvement performance. This can be done by referring to Figures 6.2 to 6.4 or simulating the design using MUSIC.

6.3.8 Step 8: Vegetation Specification

Refer to Section 6.4 and Chapter 12 for advice on selecting suitable plant species for constructed wetlands in Brisbane.

6.3.9 Step 9: Maintenance Plan

Maintenance (particularly access for maintenance) needs to be considered throughout the design and site layout process. In addition, a maintenance plan will be required that describes the frequency, tasks and methods of maintenance necessary. This maintenance plan should be updated a minimum of every three years. Refer to Section 6.5 for discussion of maintenance requirements for wetlands and requirements for maintenance plans.

6.3.10 Design Calculation Summary

Following is a design calculation summary sheet for the key design elements.
### CONSTRUCTED WETLANDS CALCULATION SUMMARY

<table>
<thead>
<tr>
<th>Calculation Task</th>
<th>Outcome</th>
<th>Check</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Catchment Characteristics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catchment area</td>
<td>Ha</td>
<td></td>
</tr>
<tr>
<td>Catchment land use (i.e residential, commercial etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm event entering inlet pond (minor or major)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conceptual Design</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Macrophyte zone area</td>
<td>m&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Permanent pool level of macrophyte zone</td>
<td>m AHD</td>
<td></td>
</tr>
<tr>
<td>Extended detention depth (0.25-0.5m)</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>Notional detention time</td>
<td>hrs</td>
<td></td>
</tr>
<tr>
<td><strong>1 Verify size for treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated water quality treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total suspended solids (Figure 6.2)</td>
<td>% removal</td>
<td></td>
</tr>
<tr>
<td>Total phosphorus (Figure 6.3)</td>
<td>% removal</td>
<td></td>
</tr>
<tr>
<td>Total nitrogen (Figure 6.4)</td>
<td>% removal</td>
<td></td>
</tr>
<tr>
<td>Macrophyte area</td>
<td>m&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td><strong>2 Determine design flows</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Design operation flow’ (1 year ARI)</td>
<td>'Design' year ARI</td>
<td></td>
</tr>
<tr>
<td>‘Above design flow’ (either 2, 50 or 100 year ARI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of concentration</td>
<td>Refer to BCC Subdivision and Development Guidelines and QUDM minutes</td>
<td></td>
</tr>
<tr>
<td>Identify rainfall intensities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Design operation flow’ - I&lt;sub&gt;1&lt;/sub&gt; year ARI</td>
<td>mm/hr</td>
<td></td>
</tr>
<tr>
<td>‘Above design flow’ - I&lt;sub&gt;2&lt;/sub&gt; year ARI or I&lt;sub&gt;50&lt;/sub&gt; or I&lt;sub&gt;100&lt;/sub&gt; year ARI</td>
<td>mm/hr</td>
<td></td>
</tr>
<tr>
<td>Peak design flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Design operation flow’ - 1 year ARI</td>
<td>m&lt;sup&gt;3&lt;/sup&gt;/s</td>
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</tr>
<tr>
<td>‘Above design flow’ - 2 or 50 year ARI</td>
<td>m&lt;sup&gt;3&lt;/sup&gt;/s</td>
<td></td>
</tr>
<tr>
<td><strong>3 Design inlet zone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refer to sedimentation basin (Chapter 4) for detailed check sheet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is a GPT required?</td>
<td>Suitable GPT selected and maintenance considered?</td>
<td></td>
</tr>
<tr>
<td>Inlet zone size</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Target Sediment Size for Inlet Zone</td>
<td>µm</td>
<td></td>
</tr>
<tr>
<td>Capture efficiency</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Inlet zone area (Figure 4.2 in Chapter 4)</td>
<td>m&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>V&lt;sub&gt;a&lt;/sub&gt; &gt; V&lt;sub&gt;5yr&lt;/sub&gt;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlet zone connection to macrophyte zone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overflow pit crest level</td>
<td>m AHD</td>
<td></td>
</tr>
<tr>
<td>Overflow pit dimension</td>
<td>L x W</td>
<td></td>
</tr>
<tr>
<td>Provision of debris trap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connection pipe dimension</td>
<td>mm diam</td>
<td></td>
</tr>
<tr>
<td>Connection pipe invert level</td>
<td>m AHD</td>
<td></td>
</tr>
<tr>
<td>High flow by-pass weir</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weir Length</td>
<td>m</td>
<td></td>
</tr>
<tr>
<td>High flow by-pass weir crest level (top of extended detention)</td>
<td>m AHD</td>
<td></td>
</tr>
<tr>
<td><strong>4 Designing the macrophyte zone</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area of Macrophyte Zone</td>
<td>m&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>L:W</td>
<td></td>
</tr>
</tbody>
</table>
5 Design macrophyte zone outlet
   Riser outlet
   Target maximum discharge \( (Q_{\text{max}}) \) m³/s

   Uniform Detention Time Relationship for Riser

   Maintenance Drain
   Maintenance drainage rate (drain over 12hrs) m³/s
   Diameter of maintenance drain pipe mm
   Diameter of maintenance drain valve mm

   Discharge Pipe
   Diameter of discharge pipe mm

6 Design high flow by-pass ‘channel’

   Longitudinal slope %
   Base width m
   Batter slopes H:V

7 Verification checks

   Macrophyte zone re-suspension protection

   Confirm treatment performance

6.4 Landscape Design Notes

6.4.1 Objectives

Landscape design for constructed wetlands has six key objectives:

1. Addressing stormwater quality objectives by incorporating appropriate plant species that suit the depth range of a wetland zone and have the structural characteristics to perform particular treatment processes (e.g. well distributed flows, enhance sedimentation, maximise surface area for the adhesion of particles and provide a substratum for algal epiphytes and biofilms).

2. Ensuring that the overall landscape design for the wetland integrates with its host natural and/or built environment.

3. Incorporating Crime Prevention Through Environmental Design (CPTED) principles (refer Section 6.4.7).

4. Providing other landscape values, such as shade, amenity, character and place making.

5. Providing habitat for local wildlife

6. Ensuring that the plant populations is self sustaining

Comprehensive site analysis should inform the landscape design as well as road layouts, maintenance access points and civil works. Existing site factors such as roads, buildings, landforms, soils, plants, microclimates, services and views should be considered. Refer to \textit{Water Sensitive Urban Design in the Sydney Region: ‘Practice Note 2 – Site Planning’} (LHCCREMS 2002) for further guidance.

If sited within accessible open space, constructed wetlands can be significant features within the built environment. Landscape design also has a key role in overcoming the negative perceptions that permanent water bodies, like sedimentation basins, have in some communities. In the past this may have been due to legitimate pest and safety concerns that have arisen from poorly designed and/or managed systems, particularly remnant swamps and lagoons. Creative landscape design can enhance the appeal and sense of tranquillity that wetlands provide.
6.4.2 Appropriate Plant Species

Planting for constructed wetlands may consist of up to three vegetation types:

- macrophyte zone planting consisting of ephemeral marsh, shallow marsh, marsh and deep marsh (from 0.5 m below to 0.2 m above design water level)
- embankment (littoral) vegetation (greater than 0.2 m above design water level)
- terrestrial plants, including existing vegetation, adjacent to the embankment edge.

6.4.2.1 Macrophyte Zone Planting (from 0.5 m below to 0.2 m above design water level)

Chapter 12 provides guidance on selecting suitable plant species and cultivars that deliver the desired stormwater quality objectives for constructed wetlands. In general, macrophyte vegetation should provide:

- well distributed flows
- enhanced sedimentation
- maximum surface area for the adhesion of particles
- a substratum for algal epiphytes and biofilms.

Additionally, ephemeral marsh planting should provide a dense buffer between the water body and publicly accessible open space to discourage contact with the water.

6.4.2.2 Embankment (Littoral) Vegetation (greater than 0.2 m above design water level) and Parkland Vegetation

Between the macrophyte zone and the top of the embankment trees, shrubs and groundcovers can be selected. Important considerations include:

- Selecting groundcovers, particularly for slopes greater than 1 in 3, with matting or rhizomataceous root systems to assist in binding the soil surface during the establishment phase. Example species include Imperata cylindrica, Lomandra sp. and Cyndodacton sp.
- Preventing macrophyte zone plants from being shaded out by minimising tree densities at the water’s edge and choosing species such as Melaleuca that allow sunlight to penetrate the tree canopy.
- Locating vegetation to allow views of the wetland and its surrounds whilst discouraging the public from accessing the water body.

Parkland vegetation may be of a similar species to the embankments littoral vegetation and layout to visually integrate the sedimentation basin with its surrounds. Alternatively, vegetation of contrasting species and/or layout may be selected to highlight the water body as a feature within the landscape. Turf may be considered to achieve this goal.

A wide range of species are at the designer’s disposal depending on desired scheme. Growing Native Plants in Brisbane (BCC 2005 on-line), Successful Gardening in Warm Climates (McFarlane 1997) provide further guidance.

6.4.3 Specific Landscape Considerations

Numerous opportunities are available for creative design solutions for specific elements. Close collaboration between landscape designer, hydraulic designer, civil/ structural engineer and maintenance personnel is essential. In parklands and residential areas, the aim is to ensure elements are sympathetic to their
surroundings and are not overly engineered or industrial in style and appearance. Additionally, landscape design to specific elements should aim to create places that local residents and visitors will come to enjoy and regard as an asset.

6.4.3.1 Wetland Siting and Shape

Once the general location has been determined, investigate how the wetland elements will be arranged within the open space. The design process should explore the opportunities and constraints presented by various siting options. Once the overall shape has been determined, one of the first considerations should be if a formal or informal style is required depending on the setting.

6.4.3.2 Crossings

Given the size and location of wetland systems, it is important to consider if access is required across the wetland as part of an overall pathway network and maintenance requirement. Factors that should be considered include:

- The appropriateness of hardwood timber board walks given their life-cycle costs. Where walkway footings are in contact with water, Council will not accept timber piers.
- If boardwalks are used, they should not be located near open water where they could encourage the public to feed wildlife.
- The use of earth bunds as crossings with culverts below. This approach allows some cut material (non-dispersive soils only) to be used on site and can be planted as a shaded walkway. They should be located within the ephemeral marsh zone of constructed wetlands or between the sedimentation basin and first macrophyte zone. Earth bund crossings can be shaped and planted to discourage wildlife feeding. Figure 6.10 illustrates a conceptual earth bund walkway.

6.4.3.3 Wetland Embankments

The landscape design approach for the wetland embankments is similar to the approach taken for embankments in sedimentation basins. Refer to Chapter 4, Section 4.4.3.3 for guidance.

Figure 6.10: Earth Bund Structure as Wetland Crossing
6.4.3.4 High Flow Bypass Channel

The high flow bypass channel will convey flood waters during peak storm events. As these elements are generally turfed, it is worthwhile investigating the recreation opportunities offered at times outside of flood events.

Designers should also investigate the opportunities for locating trees and other vegetation types within the bypass channel. Provided hydraulic efficiencies can be accommodated, grassed mounds and landform grading of the embankment edge could also be explored to add variation and interest.

The relationship between the high flow bypass channel and the permanent water bodies should be considered in order to create interesting spaces and forms within the open space. For example, after consideration of site constraints and hydraulic parameters, designers could investigate options to separate the elements from each other or to channel both elements alongside each other. Opportunities should also be sought to achieve balanced cut and fill earthworks. Figure 6.11 (following page) provides an illustration of creation of open spaces through configuration of key wetland components.

6.4.3.5 Macrophyte Zone Outlet Structure

Landscape design approach for the macrophyte outlet zone is similar to the approach taken for overflow pits in sedimentation basins. Refer to Chapter 4, Section 4.4.3.5 for further guidance.

6.4.3.6 Viewing Areas

Refer to Chapter 4, Section 4.4.3.7 for guidance.

6.4.3.7 Fencing

Refer to Chapter 4, Section 4.4.3.8 for guidance.

6.4.3.8 Signage and interpretation

Refer to Chapter 4, Section 4.4.3.9 for guidance.
6.4.4 Sourcing Plant Stock

To ensure the specified plant species are available in the required numbers and of adequate maturity in time for wetland planting, it is essential to notify nurseries early for contract growing. When early ordering is not undertaken, the planting specification may be compromised due to sourcing difficulties, resulting in poor vegetation establishment and increased initial maintenance costs. The species listed in Table 12.2 (Chapter 12) are generally available commercially from local native plant nurseries but availability is dependent upon

Landscape design should explore options for siting the bypass, wetland and basin and analyse the potential for enhanced amenity. This process should initially take place at the concept development phase and can be refined during the detailed design.

Figure 6.11: Example Relationship between High Flow Bypass, Wetland and Basin and the Creation of Open Space
many factors including demand, season and seed availability. To ensure the planting specification can be accommodated the minimum recommended lead time for ordering is 3-6 months. This generally allows adequate time for plants to be grown to the required size. The following sizes are recommended as the minimum:

- **Viro Tubes** 50 mm wide x 85 mm deep
- **50 mm Tubes** 50 mm wide x 75 mm deep
- **Native Tubes** 50 mm wide x 125 mm deep

A system of interlocking plantings/containers is recommended for initial wetland planting, particularly for deep marsh and marsh zones. This involves a series of plants (usually 5) grown together in a single ‘strip’ container. Generally, more mature plants with developing rhizomes (for rhizomatous species), are grown together creating interlocking roots. This has been used very successfully in wetland planting previously because the larger more mature plants, often with a thick rhizome system, can survive in deeper water and are more tolerant to fluctuations in water level. The structure of this system slows the movement of water and binds the substrate, helping to reduce erosion. The weight of the interlocking plants also prevents birds from removing them, a common problem encountered during wetland plant establishment. Nurseries require a minimum lead time of 6 months for supply of these systems.

### 6.4.5 Topsoil Specification and Preparation

The provision of suitable topsoil in wetlands is crucial to successful macrophyte establishment and to the long term functional performance of the wetland. Wetland macrophytes typically prefer medium textured silty to sandy loams that allow for easy rhizome and root penetration. Although there are a few plants that can grow in in-situ heavy clays (e.g. *Phragmites*), growth is slow and the resulting wetland system will have low species richness, which is undesirable. The wetland must therefore have a layer of topsoil no less than 200 mm deep.

During the wetland construction process, topsoil is to be stripped and stockpiled for possible wetland reuse as a plant growth medium. Most terrestrial topsoils provide a good substratum for wetlands, nonetheless laboratory soil testing (using Australian Standard testing procedures) of the in-situ topsoil is necessary to ensure the topsoil will support plant and microbial growth and have a high potential for nutrient retention. Typically, standard horticultural soil analysis, which includes major nutrients and trace elements, is suitable for topsoils intended for wetland use. The laboratory report will indicate the soils suitability as a plant growth medium and if any amendments are required.

If the in-situ topsoil is found to contain high levels of salt, extremely low levels of organic carbon (<< 5 %), or any other extremes that may be considered a retardant to plant growth, it should be rejected.

If the in-situ topsoil is not suitable and soil amendment is considered impractical or not cost effective, sandy loam topsoil should be purchased from a soil supplier. If the local topsoil is suitable but very shallow, mixing with an imported soil will be necessary to reach the required volume to ensure a minimum 200 mm deep topsoil for wetland planting.

Imported topsoils are generally suitable as wetland plant growth medium, however as for in-situ soils (above), testing is required to determine the appropriate gypsum or lime dosing rate. If the local topsoil was tested and found to be suitable but then mixed with an imported soil to meet the required volume, laboratory soil testing should be repeated.

Any imported soils must not contain Fire Ants. A visual assessment of the soils is required and any
machinery should be free of clumped dirt. Soils must not be brought in from Fire Ant restricted areas.

6.4.5.1 Topsoil Treatments

The wetland topsoil should be tested in accordance with AS 4419-2003: *Soils for landscaping and garden use* to ensure it is appropriate for growth of vegetation. If testing finds the topsoil is not appropriate then an alternative source should be found.

Topsoils for wetlands generally do not require fertiliser treatment. Imported foreign loam will contain sufficient nutrients for vegetation growth and local terrestrial topsoil will release nutrients after the wetting process. Submersion of terrestrial soils in water causes a shift from aerobic to anaerobic processes, prompting mineralisation and decomposition of organic matter contained in the soil, thus increasing available nitrogen. When soils become anaerobic, reduction processes cause iron oxides to be released from the surface of soil particles leading to increased availability of phosphorus. The addition of nutrients (fertiliser application) can facilitate the growth of algae (including cyanobacteria (blue-green algae), particularly when the competing macrophytes and submerged plants are in the early stages of development, increasing the likelihood of algal blooms.

The topsoil within the wetland (macrophyte zones and open water zones) may need to be treated with gypsum or lime. The application of gypsum is standard on most construction sites for the purpose of securing or flocculating dispersive soils if entrained in runoff. The use of gypsum in wetland should only occur within catchments with dispersive soils and applied at a maximum rate of 0.4 kg/m². The application of lime may be required where the AS4419 (2003) soil testing identifies a potential soil pH problem (PH < 5) or where acid sulfate soils (ASS) exist in the vicinity of the wetland. The rate of lime application should be guided by soil test results, an ASS Management Plan and water quality (pH) monitoring of the wetland and inflow.

Gypsum/lime should be applied about one week prior to vegetation planting. Subsequent application may be required at intervals depending on water quality monitoring. Application of gypsum/lime too far in advance of planting may lead to aquatic conditions that promote algal growth (i.e. clear water with no aquatic plants competing for resources).

6.4.6 Vegetation Establishment

Timing of vegetation planting is dependent on a suitable time of year (and potential irrigation requirements) as well as timing in relation to the phases of development. In Brisbane, October and November are considered an ideal time to plant vegetation in treatment elements. This allows for adequate establishment/root growth before the heavy summer rainfall period but also allows the plants to go through a growth period soon after planting, resulting in quicker establishment. Planting late in the year also avoids the dry winter months, reducing maintenance costs associated with watering.

To ensure successful plant establishment, the following weed control measures, watering schedules and water level manipulation is recommended. Regular general maintenance as outlined in the Section 6.5 will also be required.

6.4.6.1 Weed Control

Conventional surface mulching of the wetland littoral berms with organic material like tanbark is not recommended. Most organic mulch floats and water level fluctuations and runoff typically causes this material to be washed into the wetland with a risk of causing blockages to outlet structures. Mulch can also increase the wetland organic load, potentially increasing nutrient concentrations and the risk of algal blooms. Adopting high planting density rates and if necessary applying a suitable biodegradable erosion control
matting to the wetland batters (where appropriate), will help to combat weed invasion and will reduce maintenance requirements for weed removal. If the use of mulch on the littoral zones is preferred, it must be secured in place with appropriate mesh or netting (e.g. jute mesh).

6.4.6.2 Watering

Regular watering of the littoral and ephemeral marsh zone vegetation during the plant establishment phase is essential for successful establishment and healthy growth. The frequency of watering to achieve successful plant establishment is dependent upon rainfall, maturity of planting stock and the water level within the wetland. However, the following watering program is generally adequate but should be adjusted (i.e. increased) as required to suit site conditions:

- Week 1-2 3 visits/ week
- Week 3-6 2 visits/ week
- Week 7-12 1 visit/ week

After this initial three month period, watering may still be required, particularly during the first winter (dry period). Watering requirements to sustain healthy vegetation should be determined during ongoing maintenance site visits.

6.4.6.3 Water Level Manipulation

To maximise the chances of successful vegetation establishment, the water level of the wetland system is to be manipulated in the early stages of vegetation growth. When first planted, vegetation in the deep marsh and pool zones may be too small to be able to exist in their prescribed water depths (depending on the maturity of the plant stock provided). Macrophytes intended for the deep marsh sections will need to have half of their form above the water level, which may not be possible if initially planted at their intended depth. Similarly, if planted too deep, the young submerged plants will not be able to access sufficient light in the open water zones. Without adequate competition from submerged plants, phytoplankton (algae) may proliferate.

The water depth must be controlled in the early establishment phase. This can be achieved by closing off the connection between the inlet zone and the macrophyte zone (i.e. covering the overflow pit) and opening the maintenance drain. The deep marsh zones should have a water depth of approximately 0.2 m for at least the first 6 - 8 weeks. This will ensure the deep marsh and marsh zones of the wetland are inundated to shallow depth and the shallow marsh zone remains moist (muddy) providing suitable conditions for plant establishment. Seedlings planted in the ephemeral marsh and littoral zones of the wetland will require ongoing watering at a similar rate as the terrestrial landscape surrounding the wetland (Section 6.4.6.2). When it is evident that the plants are establishing well and growing actively, a minimum of 6 - 8 weeks following planting, the plants should be of sufficient stature to endure deeper water. At this time, the connection between the inlet pond and the macrophyte zone can be temporarily opened to allow slow filling of the wetland to the design operating water level.

6.4.7 Safety Issues

6.4.7.1 Crime Prevention Through Environmental Design (CPTED)

The standard principles of informal surveillance, exclusion of places of concealment and open visible areas apply to the landscape design of wetlands. Where planting may create places of concealment or hinder informal surveillance, groundcovers and shrubs should not generally exceed 1 meter in height. Refer to
6.4.7.2 Restricting Access to Open Water

Fences or vegetation barriers to restrict access should be incorporated into wetland areas, particularly on top of concrete or stone walls where:

- there is a risk of serious injury in the event of a fall (over 0.5 m high and too steep to comfortably walk up/down or the lower surface or has sharp or jagged edges)
- there is a high pedestrian or vehicular exposure (on footpaths, near bikeways, near playing/sporting fields, near swings and playgrounds etc)
- where water ponds to a depth of greater than 300 mm on a constructed surface of concrete or stone. Natural water features are exempt
- where the water is expected to contain concentrated pollutants
- where grassed areas requiring mowing abut the asset.

Fences considered appropriate are:

- pool fences (for areas adjacent to playgrounds/sports fields where a child drowning or infection hazard is present)
- galvanised tubular handrails (without chain wire) in other areas
- dense vegetative hedges.

Dense littoral planting around the wetland and particularly around the deeper open water pools of the inlet zone (with the exception of any maintenance access points), will deter public access to the open water and create a barrier to improve public safety. Careful selection of plant species (e.g. tall, dense or ‘spiky’ species) and planting layouts can improve safety as well as preventing damage to the vegetation by trampling.

Dense vegetation (hedge) at least 2 m wide and 1.2 m high (minimum) may be suitable if vandalism is not a demonstrated concern (this may be shown during the initial 12 month maintenance period). A temporary fence (e.g. 1.2 m high silt fence) will be required until the vegetation has established and becomes a deterrent to pedestrians/cyclists.

An alternative to the adoption of a barrier/fence is to provide a 2.4 m safety bench that is less than 0.2 m deep below the permanent pool level around the waterbody. This is discussed in Chapter 4 Section 4.3.3.3 with respect to appropriate batter slopes.

6.5 Maintenance Requirements

Wetlands treat runoff by filtering it through vegetation and providing extended detention to allow sedimentation to occur. In addition, they have a flow management role that needs to be maintained to ensure adequate flood protection for local properties and protection of the wetland ecosystem.

Maintaining healthy vegetation and adequate flow conditions in a wetland are the key maintenance considerations. Weeding, planting, mowing and debris removal are the dominant tasks (but should not include use of herbicides as this affects water quality). In addition, the wetland needs to be protected from high loads of sediment and debris and the inlet zone needs to be maintained in the same way as sedimentation basins (see Chapter 4). Routine maintenance of wetlands should be carried out once a month.
The most intensive period of maintenance is during plant establishment period (first two years) when weed removal and replanting may be required. It is also the time when large loads of sediments could impact on plant growth, particularly in developing catchments with poor building controls. Debris removal is an ongoing maintenance function. If not removed, debris can block inlets or outlets, and can be unsightly if in a visible location. Inspection and removal of debris should be done regularly.

Typical maintenance of constructed wetlands will involve:

- desilting the inlet zone following the construction/ building period
- routine inspection of the wetland to identify any damage to vegetation, scouring, formation of isolated pools, litter and debris build up or excessive mosquitoes
- routine inspection of inlet and outlet points to identify any areas of scour, litter build up and blockages
- removal of litter and debris
- removal and management of invasive weeds
- repair to wetland profile to prevent the formation of isolated pools
- periodic (usually every 5 years) draining and desilting of the inlet pond
- regular watering of littoral vegetation during plant establishment
- water level control during plant establishment
- replacement of plants that have died (from any cause) with plants of equivalent size and species as detailed in the planting schedule
- vegetation pest monitoring and control.

Inspections are recommended following large storm events to check for scour and damage.

All maintenance activities must be specified in a maintenance plan (and associated maintenance inspection forms) to be developed as part of the design procedure (Step 9). Maintenance personnel and asset managers will use this plan to ensure the wetlands continue to function as designed. To ensure maintenance activities are appropriate for the wetland as it develops, maintenance plans should be updated a minimum of every three years.

In accordance with the *Subdivision and Development Guidelines* (BCC 2000b), the maintenance plans and forms must address the following:

- inspection frequency
- maintenance frequency
- data collection/ storage requirements (i.e. during inspections)
- detailed clean-out procedures (main element of the plans) including:
  - equipment needs
  - maintenance techniques
  - occupational health and safety
  - public safety
  - environmental management considerations
  - disposal requirements (of material removed)
  - access issues
  - stakeholder notification requirements
  - data collection requirements (if any)
- design details.
For further details relating to maintenance plans, refer to Part C of the Subdivision and Development Guidelines (BCC 2000b). An approved maintenance plan is required prior to asset transfer to BCC.

An example operation and maintenance inspection form is included in the checking tools provided in Section 6.6. These forms must be developed on a site specific basis as the configuration and nature of constructed wetlands varies significantly.

6.6 Checking Tools

This section provides a number of checking aids for designers and Council development assessment officers. In addition, Section 6.6.5 provides general advice for the construction and establishment of wetlands and key issues to be considered to ensure their successful establishment and operation, based on observations from construction projects around Australia. The following checking tools are provided:

- Design Assessment Checklist
- Construction Inspection Checklist (during and post)
- Operation and Maintenance Inspection Form
- Asset Transfer Checklist (following ‘on-maintenance’ period).

6.6.1 Design Assessment Checklist

The checklist overleaf presents the key design features to be reviewed when assessing a design of a wetland. These considerations include configuration, safety, maintenance and operational issues that should be addressed during the design phase. Where an item results in an ‘N’ when reviewing the design, referral should be made back to the design procedure to determine the impact of the omission or error. In addition to the checklist, a proposed design must have all necessary permits for its installations. Council development assessment officers will require supporting evidence/proof from the developer that all relevant permits are in place.
## Wetland Design Assessment Checklist

<table>
<thead>
<tr>
<th>Wetland Location</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydraulics:</td>
<td>Design operational flow: (m³/s)</td>
<td>Above design flow: (m³/s)</td>
</tr>
<tr>
<td>Area:</td>
<td>Catchment Area: (ha)</td>
<td>Wetland Area: (ha)</td>
</tr>
</tbody>
</table>

### Treatment
- **Y** Yes
- **N** No
- Treatment performance verified from curves?

### Inlet Zone
- **Y** Yes
- **N** No
- Discharge pipe/structure to inlet zone sufficient for maximum design flow?
- Scour protection provided at inlet for inflow velocities?
- Configuration of inlet zone (aspect, depth and flows) allows settling of particles >125µm?
- Bypass weir incorporated into inlet zone?
- Bypass weir length sufficient to convey ‘above design flow’?
- Bypass weir crest at macrophyte zone top of extended detention depth?
- Bypass channel has sufficient capacity to convey ‘above design flow’?
- Bypass channel has sufficient scour protection for design velocities?
- Inlet zone connection to macrophyte zone overflow pit and connection pipe sized to convey the design operation flow?
- Inlet zone connection to macrophyte zone allows energy dissipation?
- Structure from inlet zone to macrophyte zone enables isolation of the macrophyte zone for maintenance?
- Inlet zone permanent pool level above macrophyte permanent pool level?
- Maintenance access allowed for into base of inlet zone?
- Public safety design considerations included in inlet zone design?
- Where required, gross pollutant protection measures provided on inlet structures (both inflows and to macrophyte zone?)

### Macrophyte Zone
- **Y** Yes
- **N** No
- Extended detention depth >0.25m and <0.5m?
- Vegetation bands perpendicular to flow path?
- Appropriate range of macrophyte vegetation (ephemeral, shallow, marsh, deep marsh)?
- Sequencing of vegetation bands provides continuous gradient to open water zones?
- Vegetation appropriate to selected band?
- Aspect ratio provides hydraulic efficiency >=0.5?
- Velocities from inlet zone <0.05 m/s or scouring protection provided?
- Public safety design considerations included in macrophyte zone (i.e. batter slopes less than 5(H):1(V))?
- Maintenance access provided into areas of the macrophyte zone (especially open water zones)?
- Safety audit of publicly accessible areas undertaken?
- Freeboard provided above extended detention depth to define embankments?

### Outlet Structures
- **Y** Yes
- **N** No
- Riser outlet provided in macrophyte zone?
- Notional detention time of 48-72 hours?
- Orifice configuration allows for a linear storage-discharge relationship for full range of the extended detention depth?
- Maintenance drain provided?
- Discharge pipe has sufficient capacity to convey maximum of either the maintenance drain flows or riser pipe flows with scour protection?
- Protection against clogging of orifice provided on outlet structure?
# 6.6.2 Construction Checklist

## Wetland Construction Inspection Checklist

<table>
<thead>
<tr>
<th>Items inspected</th>
<th>Checked</th>
<th>Satisfactory</th>
<th>Items inspected</th>
<th>Checked</th>
<th>Satisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DURING CONSTRUCTION</strong></td>
<td></td>
<td></td>
<td><strong>D. Structural components (continued)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Preliminary Works</td>
<td></td>
<td></td>
<td>1. Erosion and sediment control plan adopted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Limit public access</td>
<td></td>
<td></td>
<td>18. Concrete and reinforcement as designed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Location same as plans</td>
<td></td>
<td></td>
<td>19. Inlets appropriately installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Site protection from existing flows</td>
<td></td>
<td></td>
<td>20. Inlet energy dissipation installed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. All required permits in place</td>
<td></td>
<td></td>
<td>21. No seepage through banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Earthworks</td>
<td></td>
<td></td>
<td>22. Ensure spillway is level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Integrity of banks</td>
<td></td>
<td></td>
<td>23. Provision of maintenance drain(s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Batter slopes as plans</td>
<td></td>
<td></td>
<td>24. Collar installed on pipes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Impermeable (eg. clay) base installed</td>
<td></td>
<td></td>
<td>25. Low flow channel is adequate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Maintenance access to whole wetland</td>
<td></td>
<td></td>
<td>26. Protection of riser from debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Compaction process as designed</td>
<td></td>
<td></td>
<td>27. Bypass channel stabilised</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Placement of adequate topsoil</td>
<td></td>
<td></td>
<td>28. Erosion protection at macrophyte outlet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Levels as designed for base, benches, banks and spillway (including freeboard)</td>
<td></td>
<td></td>
<td>29. Vegetation appropriate to zone (depth)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Check for groundwater intrusion</td>
<td></td>
<td></td>
<td>30. Weed removal prior to planting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Stabilisation with sterile grass</td>
<td></td>
<td></td>
<td>31. Provision for water level control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Structural components</td>
<td></td>
<td></td>
<td>32. Vegetation layout and densities as designed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Location and levels of outlet as designed</td>
<td></td>
<td></td>
<td>33. Provision for bird protection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Safety protection provided</td>
<td></td>
<td></td>
<td>34. By-pass channel vegetated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Pipe joints and connections as designed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>FINAL INSPECTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Confirm levels of inlets and outlets</td>
<td></td>
<td></td>
<td>8. Public safety adequate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Confirm structural element sizes</td>
<td></td>
<td></td>
<td>9. Check for uneven settling of banks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Check batter slopes</td>
<td></td>
<td></td>
<td>10. Evidence of stagnant water, short circuiting or vegetation scouring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Vegetation planting as designed</td>
<td></td>
<td></td>
<td>11. Evidence of litter or excessive debris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Erosion protection measures working</td>
<td></td>
<td></td>
<td>12. Provision of removed sediment drainage area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Pre-treatment installed and operational</td>
<td></td>
<td></td>
<td>13. Evidence of debris in high flow bypass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Maintenance access provided</td>
<td></td>
<td></td>
<td>14. Macrophyte outlet free of debris</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## COMMENTS ON INSPECTION


## ACTIONS REQUIRED

1. 
2. 
3. 
4. 

Inspection officer signature:
6.6.3 Operation and Maintenance Inspection Form

The example form below should be developed and used whenever an inspection is conducted and kept as a record on the asset condition and quantity of removed pollutants over time. Inspections should occur every 1 - 6 months depending on the size and complexity of the system. More detailed site specific maintenance schedules should be developed for major constructed wetland systems and include a brief overview of the operation of the system and key aspects to be checked during each inspection.

<table>
<thead>
<tr>
<th>Wetland Maintenance Checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection Frequency: 1 to 6 monthly</td>
</tr>
<tr>
<td><strong>Location:</strong></td>
</tr>
<tr>
<td><strong>Site Visit by:</strong></td>
</tr>
<tr>
<td><strong>Inspection Items</strong></td>
</tr>
<tr>
<td>Sediment accumulation at inflow points?</td>
</tr>
<tr>
<td>Litter within inlet or macrophyte zones?</td>
</tr>
<tr>
<td>Sediment within inlet zone requires removal (record depth, remove if &gt;50%)?</td>
</tr>
<tr>
<td>Overflow structure integrity satisfactory?</td>
</tr>
<tr>
<td>Evidence of dumping (building waste, oils etc)?</td>
</tr>
<tr>
<td>Terrestrial vegetation condition satisfactory (density, weeds etc)?</td>
</tr>
<tr>
<td>Aquatic vegetation condition satisfactory (density, weeds etc)?</td>
</tr>
<tr>
<td>Replanting required?</td>
</tr>
<tr>
<td>Settling or erosion of bunds/batters present?</td>
</tr>
<tr>
<td>Evidence of isolated shallow ponding?</td>
</tr>
<tr>
<td>Damage/vandalism to structures present?</td>
</tr>
<tr>
<td>Outlet structure free of debris?</td>
</tr>
<tr>
<td>Maintenance drain operational (check)?</td>
</tr>
<tr>
<td>Resetting of system required?</td>
</tr>
<tr>
<td><strong>Comments:</strong></td>
</tr>
</tbody>
</table>