

## Chapter 17

# Planting, Selection and Plant Establishment in Constructed Wetlands in a Tropical Environment

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**Abstract.** This chapter examines plant selection, sourcing, planting and establishment in constructed wetlands. The chapter deals with surface water constructed wetlands with water quality treatment as the primary objective. However, much of the information can be readily applied to other constructed wetland types. Information presented is based on the author's experience with constructed wetland projects in Australia and South-East Asia. The aim is to provide information relevant to the establishment of a desirable crop of healthy wetland plants within constructed wetlands.

### 17.1. Introduction

Frequently the establishment of wetland plants in constructed wetlands is perceived to be relatively straight forward given the lushness of vegetation growth in tropical environments. Indeed many desirable wetland plants are considered to be problematic weeds (Sainty & Beharrell, 1998c; Tjitrosemito, 1993). However, in practice this may not be the case. Scientific literature is limited in terms of plant selection and plant establishment in constructed wetlands not only in the tropics but all regions. This chapter is based on the authors experience with surface water constructed wetlands throughout Australian and in regions of South East Asia.

Good decisions concerning plant selection and incorporation of plant requirements into the design, can prevent a wetland from being an engineering success, but a biological failure. Even rudimentary knowledge of the issues involved in planting, selection and plant establishment can enhance the development of a dense stand of desirable species. Performance of the wetland relies not only on good design, but also on good construction and operation. Healthy wetland plants are a key feature affecting the consistent performance of wetland treatment systems (Kadlec & Knight, 1996a; Adcock et al., 2000).

### ***17.1.1. What is a Constructed Wetland?***

Constructed wetlands can be considered as wetlands built to fulfill desired objectives. White (1998) defines a constructed wetland as “*purpose built structures, utilizing the predominantly natural materials of soil water and biota, which perform the desired physical, chemical and biological processes and functions of natural wetlands to achieve desired objectives.*”

The objectives of constructed wetlands will include one or more of the following (White et al., 1996):

1. water quality improvement, including municipal waste, urban stormwater, agricultural and urban run-off, industrial and mine wastewater;
2. modify water flow;
3. provision of habitat;
4. passive recreation and visual amenity;
5. public education; and
6. modify water flow.

There are also several types of constructed wetlands these include: surface water wetlands; subsurface treatment wetlands; and natural treatment wetlands (Kadlec & Knight, 1996b). This chapter looks at plant selection sourcing and establishment in surface water wetland, where the primary objective is water quality treatment.

### ***17.1.2. Roles of Water Plants in Constructed Wetlands***

Wetland plants are an important component in constructed wetlands. The roles that they can fulfill or to which they can contribute to are numerous (Gersberg et al., 1986; Mitsch & Gosselink, 1993; Chambers et al., 1995). In a surface water constructed wetland the roles of wetland plants can include:

- aiding in the biochemical processes, which reduce nutrient and other pollutant concentrations;
- influencing sediment deposition and physically filtering sediment particles from the water column;
- influencing hydrology and hydraulics in constructed wetlands by increasing flow roughness and transpiration;
- providing shade, thus decreasing light availability for algal photosynthesis;
- decreasing erosion by reducing wave energy and flow velocities while binding soil particles with their root systems;
- providing a basis for wetland food chains and supplying shelter for invertebrates, amphibians, reptiles, birds and mammals; and

- improving visual amenity by adding color, texture, contrast and variety of patterns in the landscape.

### 17.1.3. What is a Wetland Plant?

Wetland plants have adaptations that allow the transportation of oxygen to the roots and rhizomes (Brix, 1997). This oxygen is needed not only for respiration in saturated soils by root or rhizome, but also for the leakage of oxygen which prevents toxins from accumulating in the root zone under saturated conditions.

Although there are numerous definitions of a wetland plant, none are satisfactory as there are always exceptions that fall outside the definitions. However, plants that thrive and flower in soil that is saturated for long periods can be considered wetland plants (Sainty & Beharrell, 1998a). There are notable exceptions such as *Phragmites australis* (Common Reed), which will grow in damp pasture land where soil is not saturated.

Generally, wetland plants can be divided into four groups:

- (i) *Littoral plants* These species thrive in periodically flooded land and usually grow amongst species that are not strictly wetland plants. Notable species in this group are some *Juncus* spp. (Rushes) and *Cyperus* spp. (Sedges).
- (ii) *Emergent plants* Emergent plants contain most of the wetland plant species; these species grow through the water column, examples include *Eleocharis* spp. (Spikerushs) and *Scirpus* spp.
- (iii) *Submerged plants* Submerged plants are rooted or free-floating plants with their foliage entirely below the water surface. Examples include *Potamogeton* spp. (Pondweeds) and *Vallisenairia* spp.
- (iv) *Floating plants* These float at the water surface. This type includes the Duckweeds *Lemna* spp, *Spirodela* spp. and, *Azolla* spp. and the introduced noxious weeds *Salvinia molesta* and *Eichhornia crassipes* (Water Hyacinth). It also includes the floating attached plants such as *Nymphoides* spp. (Marshworts) and *Nymphaea* spp. (Water Lilies).

### 17.1.4. Plant Protection

Pre-planning to ensure planting success is necessary at the design stage of any wetland project. The success of any surface water constructed wetland will be reflected in addressing issues associated with the catchment (Sainty & Dalby-Ball, 2000). Some of which are listed below:

- Will plants be dislodged or washed away. To prevent this wetlands should be built off-line or if on-line built to appropriate sizing to dissipate velocities.

- Sediment and gross pollutants must be extracted prior to flows entering vegetated areas of the wetland. Deposition of sediment can alter surface levels within the wetland affecting wetland performance, and smother plants.
- What potential pest animals can occur in the catchment? Pests such as the *Pomacea* sp (Pink Snail; Lim et al., 1999) found in areas of South East Asia has the potential to significantly affect plantings. Waterfowl can be a significant factor, in Sydney a group of Purple Swamphens (*Porphyrio porphyrio*) are known to have decimate 10,000 seedlings in one night.
- What pest species occur in the catchment? *S. molesta* and *E. crassipes* in the upper catchment can not only lead to long-term maintenance problems but can damage plantings in high flow events.
- Are there any pollutants that may harm plants? Submerged planting, e.g. may be damaged by elevated levels of chlorine or high turbidity (Sainty & Dalby-Ball, 2000).

When designing wetlands thought must be given to planting issues. Issues include: water depth and its control; flows and velocities; and expected performance of the wetland. For example some plant species can tolerate velocities up to 2 m/s, or recover rapidly after being knocked down. However, peak velocities should be kept below 0.5 m/s, with treatment process being limited when flows exceed 0.1 m/s (Wiese, 1998).

## 17.2. Wetland Plant Selection

Plant species and diversity should be selected to match the wetland objectives. For instance, where wetlands are restored or constructed primarily for conservation reasons, plant diversity will be required. On the other hand, a monoculture may be appropriate where wetlands are constructed to assimilate wastewater. A wetland planned as a wading bird habitat may require limited or low growing vegetation to encourage roosting or nesting (Saitilan, 2002).

Species diversity provides a variety of plant growth forms, with various habitat types and food for fauna. Diversity also provides protection against plant failure, which can be caused by some plant specific diseases or pests.

Structural diversity of wetland plants can be important for other reasons. This creates a larger range of predator species able to prey on mosquitoes (Russel & Kuginis, 1998).

### 17.2.1. What are We Looking for in Wetland Plant?

Constructed wetlands are a relatively new field in South-East Asia and as such there is limited information on their use. In many cases the choice of plants has

been extrapolated from the same or similar plant species utilized elsewhere (Norazmi et al., 1999).

There are few studies on contaminant removal by wetland plants in the tropics. One investigation in Malaysia showed that all the species utilized had the potential for use in treatment wetlands. *Eleocharis dulcis* (Water Chestnut) produced the highest removal rates compared to the other species for a variety of available nutrients (Sahidin et al., 2001).

Laboratory removal rates results do not always transfer readily to field situations. This is due to the large number of variables found within constructed wetlands, particularly hydraulic and pollutant loadings. Pollutant removal rates and other characteristics of a particular species can vary on a regional basis due to genetic variability.

Most wetland species in South East Asia may play a small part in increasing diversity in a constructed wetland, but are especially suited to planting in constructed wetlands. Table 1 lists wetland plant species that have potential for use in constructed wetlands, they are found in many tropical environments in South-East Asia and Australasia. This list is by no means exclusive, and wherever constructed wetlands are proposed catchment investigations must be undertaken in order to decide which are the most appropriate species.

Generally, in surface water treatment wetlands emergent species are chosen. There are several basic requirements for wetland plants in a surface water constructed wetland. These characteristic include:

- being locally native species is an important criterion because these will be adapted to local conditions, and therefore have less potential impact on the local environment than introduced species, which are unpredictable and may cause significant environmental harm.
- having the ability to tolerate saturated soils and persistence in permanently flooded conditions.
- where possible being perennial rather than annuals.
- being robust plants which are more likely to withstand or recover from high flow events, they should also be able to tolerate variations in water depth.
- be able to produce leaf litter as sites for physiochemical activity, this is important in the processes involved in nutrient reduction with constructed wetlands (Broderick et al., 1988);
- being readily propagated; and
- having minimal weed potential, even locally native species can become significant weeds under certain circumstances.

Table 1: Some potential wetland plants for surface water constructed wetlands in the tropics.

Wetland plants	Planting depths <sup>a</sup>
<i>Cyperus compactus</i>	Littoral
<i>Cyperus digitatus</i>	Littoral
<i>Cyperus halpan</i>	Littoral
<i>Eriocaulon longifolium</i>	Littoral
<i>Eleocharis dulcis</i>	0.6–0.9 m
<i>Eleocharis variegata</i>	0.3–0.6 m
<i>Fimbristylis globulosa</i>	0–0.3 m
<i>Fimbristylis miliacea</i>	Littoral
<i>Fuirena umbellata</i>	0–0.3 m
<i>Hanguana malayana</i>	0–0.3 m
<i>Lepironia articulata</i>	0.3–0.6 m
<i>Ludwigia adscendens</i>	0–0.3 m
<i>Ludwigia octovalvis</i>	Littoral
<i>Monochoria hastata</i>	0–0.3 m
<i>Nymphaea nouchali</i>	0–0.6 m
<i>Pandanus immersus</i>	0–0.3 m
<i>Phragmites karka</i>	0–0.6 m
<i>Phragmites australis</i>	0–0.5 m
<i>Phylidrum lanuginosum</i>	0–0.6 m
<i>Polygonum barbatum</i>	0–0.3 m
<i>Rynchospora corymbosa</i>	0–0.3 m
<i>Saccharum spontaneum</i>	Littoral
<i>Scirpus grossus</i>	0–0.6 m
<i>Scirpus juncooides</i>	Littoral
<i>Scirpus mucronatus</i>	0–0.6 m
<i>Scleria sumatrensis</i>	0–0.3 m
<i>Typha angustifolia</i>	0–0.6 m
<i>Vanda hookeriana</i>	0–0.3 m

<sup>a</sup>The water depths can be variable and some species may tolerate greater depths with regular water level draw downs. Littoral refers to that area frequently inundated between operating water level to surcharge level.

### 17.2.2. Wetland Water Depths

It is important to note that there are distinct zones within a wetland in terms of water depth. Plant selection must be based on a design to ensure that they are suited to the hydrology of the new wetland. For example from the average

operating water level to the surcharge level, inundation will be relatively frequent, but of a short duration. Dry spells will also be frequent.

Matching the depth of the wetland with appropriate plant tolerances is important. Different plants tolerate different water depths. With greater depth, diversity of species will be reduced, because the majority of emergent species are discouraged by depths greater than 0.6 m. Water quality in surface water treatment wetlands and genetic variability may significantly reduce a species tolerance to water depths observed in the wild (Kadlec & Knight, 1996c).

In surface water wetlands viability of many species at depths that they would normally tolerate is diminished if water depth remains consistent. Therefore, a lowering of water depth can significantly increase the viability of many emergent species. The logical time to reduce the depth is during the dry season when inflows are reduced. Currently, there is limited information on the duration and management of this water regime for wetlands in tropical areas. Lowering of water levels may also affect the ability of surface water wetlands to meet water quality objectives and may impact on habitat requirements.

### 17.2.3. Additional Species

Where diversity of plant species is required, additional species can be introduced. These include wetland plants that do not make up the bulk of the plantings, which can be introduced readily by use of propagules, e.g. *Ipomea aquatica* (Morning Glory) and *Ludwigia adscendens* (Water Primrose).

There are several native, decorative, flowering plants that can be used in constructed wetlands. Emergent species include *Philydrum lanuginosum* (Frogsmouth) and *Monochoria hastate* and floating attached species such as *Nymphoides* spp. (Marshwort), *Nymphaea* spp. (Water Lily), Lotus (*Nelumbo* spp.) and others which have attractive flowers. However, care in placement of floating attached plants must be made to ensure objectives are not compromised. Floating and floating attached species may invade open water and vegetated areas as well as blocking structures.

Deep sections of wetlands may benefit from the addition of submerged perennial plants. In Australia, these have been shown to contain the highest macroinvertebrate diversity in treatment wetland (Ross et al., 1997). However, care must be taken to ensure that other problems are minimized, these include blockages of structures and detachment which can lead to odor problems.

In surface water wetlands floating plants such as the noxious weeds including *S. molesta*, *E. crassipes* (Water Hyacinth) and *Pistia stratiodes* (Water Lettuce) are not desirable. In eutrophic conditions they can form a dense mat across the surface of then water. This prevents reoxygenation of the water column reducing

water quality through anoxia. The mat also excludes light from the water column, reducing the diversity of fauna and the degree of pathogen disinfection by sunlight. They can also provide habitat for *Mansonia* spp. mosquitoes (Russell, 2000).

#### ***17.2.4. Trees in and Around the Wetland***

Many trees have potential to be grown in shallow wetlands provided there is an annual total draining of free water from the site. There are many trees native to the tropics tolerant of shallow flooding including the Paperbarks (*Melaleuca* spp.) and She Oaks (*Casuarina* spp.). These may be added to a wetland containing emergent wetland plants (Sainty & Beharrell, 1998a).

Careful attention must be given to the selection and placement of trees near the wetland, as shading may hinder the growth and density of wetland plants (Beharrell, 1996). Trees may need to be positioned away from the edge of the wetland to a distance equal to the maximum potential height of that species. That is, a tree with a potential height of 20 m should be planted 20 m from the edge of the wetland.

### **17.3. Sourcing Plant Material**

The propagation and supply of plant material is a booming business in the USA, Great Britain and parts of Europe (Kadlec & Knight, 1996a–c) and has rapidly expanded in Australia over that last 5 years.

Several sources and types of plant material are available for planting within the wetland and are discussed below. Certain species may be available in a particular form, e.g. in Australia, seed of *Bolboshenous fluviatalis* is rarely viable, bulbs are used instead. At any one site several types of material may be required. In the Putra Jaya project in Malaysia a mix of plant materials were used to provide the diversity and the numbers of plants required.

#### ***17.3.1. Direct Seeding***

In some situations direct seeding can be a quick and cheap method of establishing vegetation. However, it requires careful management and a good knowledge of the germination and growth requirements of the species being used. Generally, direct seeding is not a viable option for establishing the majority of vegetation in constructed wetlands due to seed and germinated seedlings being at constant risk from:

- flooding;
- predation by water fowl, insects etc.;

- desiccation;
- fungal attack; and
- weed invasion.

### **17.3.2. Translocation**

This is another form of direct seeding utilizing using the whole seed bank. The soil containing a viable seed bank is removed in layers and translocated to a suitable alternative site (Kadlec & Knight, 1996a; Brock, 1997). This method has been successfully utilized when a wetland site is to be developed and an appropriate translocation site exists. However, similar problems to direct seeding exist and precautions must be taken to ensure that major pests/diseases are not introduced.

### **17.3.3. Transplanting**

Transplanting is a process of removing plants or plant pieces from existing wetland area. Where possible, disturbance of natural wetland areas should be avoided. Plant pieces should only be taken from existing wet areas only when it has been established that removal will not damage wildlife habitats. Where diverse and large numbers of plants are required, identifying the potential areas for sourcing has to be done early.

When it is undertaken, this technique for establishing vegetation has the advantage that the transplanted stock will be relatively mature. Rhizomes or tussocks are collected by digging up existing vegetation. This method can be particularly successful for *Phragmites* spp. (Reed) and *Scripus* spp. (Clubrushes). Many species, however, will not transplant well if the leaves and stems are damaged. Root pieces must be managed carefully after extraction and kept cool.

Alternatively, harvested vegetation may be used as a propagation material for example cuttings may be taken. Propagation of *P. karka* and *P. australis* by this method has been shown to be particularly successful in Malaysia and Australia respectively.

Potential problems with transplanting including:

- the fact that only areas with large populations of the plants can be utilized and there is the potential for significant impact on the natural environment;
- the possibility of importing noxious weed species;
- that many wetland plants are large and difficult to handle;
- that large scale harvesting requires stockpiling, leading to double handling and difficulty in maintaining viability during storage;

- harvesting and transplanting, which is very labour intensive, and may require plants to be transported over significant distances; and
- ensuring safety and security during field collection (e.g. use of life jackets, protective boots, first-aid kits and protection against human pests and predators).

#### ***17.3.4. Nursery Propagation***

Nursery grown seedlings can be produced in high volumes, of even age and quality, that can be planted at any density. Nursery stock has several advantages, including:

- seedlings that are generally of a uniform height and age;
- that the maturity and quality of the plant stock can be pre-determined; and
- that accidental introduction of weed species can be minimized.

Some wetland plants are easily propagated and it may be feasible to propagate plants on-site. Propagation of nursery seedlings is relatively simple. However, a significant lead time may be required to allow for seed collection and development of propagation techniques.

Propagation by tissue culture is not recommended. Wetlands developed with plants sourced by tissue culture are derived from one or few genotypes and lack the genetic diversity obtained from using seed. Such uniform plant stock is more susceptible to predators, disease and climatic extremes (Sainty & Beharrell, 1998a).

Before purchasing seedlings for the project, it is recommended that a written guarantee is obtained stating that the seed was collected from an agreed location, and that the plant stock is weed free.

***Types of Seedlings.*** Seedlings can be propagated for a variety of plant materials. These include seeds, corms, bulbs, cuttings, and division of tussocks. The viability of these propagules is highly variable and can be dependent on genotype and climatic conditions.

Seedlings can be made available for nurseries in different sized containers reflecting the maturity of the plant stock.

Small cells (20–100 ml volume) may be suitable for some species where there is:

- a well-prepared and level substrate;
- good control over water levels; and
- the wetland is off-stream (i.e. seedlings will not be decimated in high flow events).

Generally, larger cells with a volume over 200 ml are more robust and will have a higher rate of success. While seedling size is important, there are variations

between species. For some species, increasing the size of the seedlings purchased and decreasing the planting density may be appropriate. The more mature and healthy the seedling, the greater the chance of survival. All seedlings must be “Hardened-off” prior to planting to minimize any planting trauma.

**Plants Strips.** Frequently used in USA and Australia are strips of mature plants specially grown and subsequently harvested. This provides a mature plant product similar to grass turf, which can be readily laid within the wetland. Whilst the cost is significantly greater it provides an instant result and can be used to establish vegetation at a quicker rate.

### 17.3.5. Planting Design

A planting design is a plan showing placement within a wetland. A planting design will allow the area for each plant species to be pre-determined. Numbers of each species required can then be estimated using the plant densities for that species. The planting design will make management of planting simpler. Areas and densities should be shown to scale on the design.

Surface water treatment wetlands are often planted with emergent species in bands at right angles to flow. Water flowing into the wetland then passes through a uniform vegetated band reducing the possibility of water finding the path of least resistance (i.e. short circuiting). It is important to differentiate littoral vegetation from other water plants. Littoral species can tolerate inundation and/or shallow depths (up to 200 mm) but are also adapted to extended dry periods. These species should be planted in a littoral zone where intermittent inundation will occur. In the reed bed zone, emergent vegetation adapted to deeper and more permanent water levels is required.

If continued diversity is an objective rapidly spreading rhizomatous wetland plants are best planted next to strong competitors. Thus the rapidly spreading *P. karka* should not be planted next to slow growing *Eleocharis* spp. (Spikerush). *Phragmites* spp. (Reed) are aggressive, fast-spreading clonal species which have demonstrated the capacity to dominate a wetland over time reducing diversity. Growth rate, speed of spread and ultimate vigor are all factors in deciding where to position wetland plants.

### 17.3.6. Planting Density

Planting densities vary from 1 plant/5 m<sup>2</sup> for *Melaleuca* spp. (Paperbark) to 8 plants/m<sup>2</sup> for some emergent plants. Densities depend on:

- the plant material used;
- growth rates of species; and
- the nature of the root system.

Rhizomatous species such as *S. grossus* and *P. karka* are capable of spreading many meters in a few months and 6 plant/m<sup>2</sup> may be sufficient. Tufted species such as *S. mucronata* may require a density of at least 10 plants/m<sup>2</sup>. Densities must be high enough to crowd out weed species.

In the Putra Jaya Project in Malaysia planting densities of 12 plants/m<sup>2</sup> for large seedlings have been used with outstanding success. In Australia densities as low as 4 plants/m<sup>2</sup> for similar plant material have been used successfully where ideal plant establishment conditions existed.

Planting density has a significant influence on the cost of establishing a wetland. It can also be influenced by other factors including:

- time of planting (i.e. season);
- quality of substrate preparation;
- ability to provide adequate establishment conditions; and
- plant material used.

### ***17.3.7. Seed Collection***

For seed collection, timing is important to ensure that the fruits/seeds are mature at collection. If seeds have to be collected, requests for supply should be made a minimum of 12 months prior to planting, as different species may set seed at different times of the year. If propagation is delayed there is potential for losses due to using immature plants.

## **17.4. Planting**

Generally, the type of plant material used determines planting techniques. The key to successful planting is to minimize the transplant shock during planting.

### ***17.4.1. Planting Timeframes***

The planting and establishment of wetland vegetation is crucial for the success of constructed wetlands. Depending on wetland objectives and planting techniques, planting may not be required, or proponents may rely on natural revegetation and colonization for plant establishment. However, such situations are not common.

Planting is dependent on wetland construction being completed and so it is important to determine construction and subsequent planting timeframes. Planting should occur as soon after preparation of the wetland substrate as possible to reduce the chance of the substrate being either eroded or invaded by weeds.

There are several factors that affect the establishment of a dense cover of vegetation in a constructed wetland, including:

1. correct placement of various species within the wetland;
2. quality of plant material;
3. preparation of the planting substrate;
4. planting techniques minimizing shock to the transplanted stock; and
5. provision of ideal conditions for plant establishment.

#### ***17.4.2. Planting Substrate***

Within constructed wetlands a planting substrate to support plant growth is provided on the subsoil exposed by excavation. This exposed subsoil will usually be too compacted to allow plant root growth and may also lack nutrients. However, on occasions planting may be undertaken on undisturbed sites with no substrate. In these instances it will be necessary to control the existing vegetation.

In subsurface flow wetlands a specific substrate will be required to support plant growth whilst allowing water movement.

#### ***17.4.3. Selection of Substrate***

The provision of an appropriate substrate can be the key to successful plant establishment (Norazmi et al., 1999). The selection of a suitable substrate is based on horticultural principles, i.e. plants need support, ability for roots to grow downwards and nutrients. Friability for root growth is very important dense soils such as clays will prevent root growth. Soils with a clay content greater than 20% may be problematic.

For a surface water system the minimum depth of any substrate should be 250 mm. It is more convenient and less costly if substrates can be used from the wetland construction site. This should be identified in site investigations. In such situations, the substrate material should be carefully stockpiled and protected against erosion for later placement in the wetland.

Substrate materials should be physically and chemically suited to their intended location within the wetland. For instance, highly erodable materials should not be chosen for high energy areas of wetlands. Similarly, wetland

substrates should be inherently chemically stable, e.g. non-dispersive (Sainty & Beharrell, 1998b).

Fertilizer may be used where the substrate is poor and devoid of nutrients: in Australia soils with total available phosphorus less than 5 mgP/kg are considered nutrient poor. A controlled-release fertilizer can be used (Kuginis et al., 1998), however, slow release fertilizer must be specifically designed to tolerate the continuous wet conditions (Jacobs, 2000).

Substrates may also contain many weed seeds, especially those derived from other wetland areas, floodplains, riverbeds, etc. The use of substrate material known to come from an area with weed populations should be avoided.

#### ***17.4.4. Preparation of Substrate***

If substrate preparation has been poor and levels are uneven, the wetland will not drain and maintenance costs may be increased or mosquito habitat enhanced. Maintaining friability and accurate leveling are the most important aspects of substrate preparation.

The substrate needs to be placed and leveled in the wetland. Any substrate ameliorant (fertilizers, gypsum, lime, organic matter, etc.) can be tyned in after placement. It is important to provide a level planting bed, but ensure that the substrate is not overworked with machinery, as this leads to a declines in substrate structure. The substrate should not be compacted.

Some substrates may be left prepared for some time before ideal conditions for planting arise. This should pose few problems as long as substrates are protected from erosion and any weed growth is treated.

#### ***17.4.5. Planting Methods for Wetlands***

Ideally, plant into damp or dry soil and irrigate after planting. Planting into wet mud or shallow free water is also possible, and depending on the circumstance may be the only practical way, but it is more time consuming.

Mechanical planting techniques are being developed and occasionally used in Australia and elsewhere to increase planting efficiency especially over large areas. Mechanical planting is restricted to planting into a dry substrate using relatively low plant densities, and may require the use of specific plant stock. Mechanical planting may damage a level substrate and plant roots.

Manual planting is the most widely used method. Manual planting allows appropriate densities, as required by the planting plan, to be realized. Manual planting can reduce damage to plant stock and lead to high plant survival

rates. If the substrate is wet or is covered by water, manual planting may be the only option available.

All members of planting groups should be briefed about the objectives of the wetland and the requirements of the planting plan prior to planting. This session can also be used to explain and demonstrate the skills and tasks for planting. Other tasks may be allocated to various team members, for example watering plants and carrying plants to those doing the planting.

At the Putra Jaya wetland project in Malaysia, laborers were able to plant approximately 800–1,000 plants per day. In Australia individuals in professional planting teams, on a well prepared substrate, can average between 1,000 and 1,200 plants per day.

#### ***17.4.6. Supervision***

Experienced personnel must always supervise the work. The ‘planting manager’ should understand the planting design and have a detailed knowledge of planting techniques for wetland species. This person should also be responsible for assigning people to the various tasks. Unless mistakes are promptly corrected, there will be a repetition of errors. The most common mistake in planting is for enthusiastic planters to plant at very high densities or use the wrong species.

The location and density of species planted in the wetland will often change from that set out on the planting design. Experience and common sense will allow decisions to be made regarding changes from the original planting design.

#### ***17.4.7. Irrigation***

In dry conditions, seedlings need to be “watered in” within a few hours of planting. Subsequent irrigation will vary according to each site. If planting is to take several days or weeks, seedlings will need to be irrigated frequently.

An alternative is to flood cells a section at a time by using berms to separate unplanted areas from planted areas. Once all areas of the wetland are planted the banks can be broken. These low banks may be covered by water at normal operational water levels.

Occupational health and safety should be an essential part of all planting activities. If the wetland receives a heavily polluted water supply, ensure that there is no free water in the wetland so that possible health risks from pathogens during planting are prevented.

#### ***17.4.8. Plant Handling***

Plant stock needs to be stored in a safe, secure location. If this location is not at the wetland site, stock should be taken to the site as required. Stored seedlings must be kept out of the sun and watered regularly. All plant stock should be labeled with the plant name and number of plants.

### **17.5. Plant Establishment**

Many project managers consider the hardest part of the project over on the completion of planting. However, if conditions to encourage plant growth are not provided, plant deaths can be expected. Plant establishment is dependent on water level control and nurturing seedlings. Inspections should be undertaken at least weekly during this stage to ensure that actions which promote growth are undertaken.

#### ***17.5.1. Managing Water Levels After Planting***

One significant impact of tropical environments is that precipitation exceeds evaporation. This means that correct water level management is crucial for plant establishment and maintenance.

During plant establishment, water levels within the wetland will need to be controlled to prevent seedlings from being desiccated due to lack of water, or drowned by excessive water levels. Initially, after planting water depths should be kept low. As a rule of thumb only one third of the shortest plant should be inundated. A common misconception of wetland plant growth is that they are dependent on elevated water levels, whereas in the majority of cases the opposite is true.

#### ***17.5.2. Weed Invasion and Plant Health***

During plant establishment the wetland should be checked regularly for plant health and weed invasion. Weed invasion is a potential hazard during plant establishment as there is little competition from desirable vegetation and a dense cover has yet to be established. Weekly inspection can reduce the potential for minor infestations becoming major problems, displacing desirable vegetation.

Plant health may suffer during plant establishment due to transplant shock, disease, pest species and/or inappropriate water levels. Regular inspections of plant health can allow steps to be taken to rectify problems quickly.

### ***17.5.3. Supplementary Planting***

In all projects there will be areas where plant survival rates are poor. Contingency funds must be made available to re-plant areas with high plant mortality. Areas devoid of plants may be susceptible to weed invasion and flow short-circuiting. Knowledge of the most successful plantings at initial planting can be utilized to select replacement species.

### ***17.5.4. Records***

Details of all plantings should be formally kept. This will enable changes in planting density and species composition to be noted, and informed decisions can then be made about future re-planting and water level management. If planting in blocks, permanent markers should be installed for monitoring purposes. This will allow the success of the planting and changes in species composition to be assessed over time.

## **17.6. Conclusion**

The establishment vegetation in constructed wetlands is dependent on attention to detail. There are many variables that need to be considered when establishing vegetation. Planning and design must take into account plant requirements specifically water depth and velocity. Potential pests, weeds and contaminants in the catchment likely to affect plant growth must be identified.

There are many plants that show potential for use in constructed wetlands in tropical climates. However, there is minimal knowledge on the propagation and requirements of these species. This is further complicated by there being likely variation based on genetic variability on a regional basis. However, it is important to ensure an appropriate water depth for the species used.

Successful growth of wetland plants is heavily dependent on the substrate of the wetland and water level control during establishment. These variables must be management successfully if a wetland is to succeed. It is during this phase that the majority of wetland plantings fail.

Wetland plants play an important role in the success of constructed wetlands. The establishment of a dense stand of desirable vegetation in a constructed wetland does not appear difficult. Currently there is limited information on plant sourcing, selection and establishment in tropical climates. With the increased use of constructed wetlands in the region the availability and development of appropriate techniques is sure to increase.

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