

Growling Grass Frog Habitat Design Standards

Melbourne Strategic Assessment



Cover image: Growling Grass Frog on a mat of Fennel Pondweed (*Stuckenia pectinata*).
Photo by Geoff Heard, University of Melbourne

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Large off-stream wetlands with dense aquatic vegetation provide breeding habitat for Growling Grass Frogs.
Photo by Damien Cook, Rakali Ecological Consulting

Introduction

The Growling Grass Frog *Litoria raniformis* is listed as a threatened species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.

It was once one of the most common frogs in south-eastern Australia but has suffered a substantial decline in range and abundance in recent decades (Clemann and Gillespie 2012). Numerous threatening processes are thought to contribute to this decline, and several of them may be acting in combination.

The Commonwealth Government approved urban development under the Melbourne Strategic Assessment on condition that, among other things, actions are undertaken in accordance with the *Biodiversity Conservation Strategy for Melbourne's Growth Corridors* (DEPI 2013a) and *Sub-regional Species Strategy for the Growling Grass Frog* (DEPI 2013b).

The Victorian Government has committed to ensuring the persistence of the Growling Grass Frog within the Melbourne Strategic Assessment program area. The *Delivering Melbourne's Newest Sustainable Communities Program Report* (DSE 2009), which specifies the program and identifies the processes and mitigation measures for the Melbourne Strategic Assessment program, outlines the activities to:

Maintain functioning sustainable populations of ... Growling Grass Frog within and adjacent to the growth corridors with connectivity between populations. Protect and enhance ... important populations of Growling Grass Frog that occur within the growth corridors.

The *Biodiversity Conservation Strategy for Melbourne's Growth Corridors* identified Growling Grass Frog conservation areas that must be protected and enhanced in order to achieve the conservation outcomes for Growling Grass Frog. The *Sub-regional Species Strategy for the Growling Grass Frog* noted that:

Growling Grass Frog populations and habitats within and outside the growth corridors need to be protected and managed on a landscape level and also on a patch or population level, where frogs have the capacity to move within and between sites. The greatest opportunity to achieve this outcome is by protecting key waterways with large buffers that allow for protection and creation of additional breeding habitat with sufficient area for foraging and dispersal between sites.

Funds collected from those developing land will be invested in the creation, enhancement and management of Growling Grass Frog habitat in conservation areas established under the *Biodiversity Conservation Strategy for Melbourne's Growth Corridors*. The *Growling Grass Frog Masterplan for Melbourne's Growth Corridors* (Masterplan – DELWP 2017) establishes priority reaches for investment of these funds in habitat creation for the Growling Grass Frog. This document is a key component of the Masterplan package.





Purpose

The *Biodiversity Conservation Strategy for Melbourne's Growth Corridors* and *Sub-regional Species Strategy for the Growling Grass Frog* addressed some of the threatening processes that are likely to be contributing to the decline of the Growling Grass Frog in the Melbourne growth corridors, but identified the need for further information and standards for some issues.

Recent ecological studies have improved our understanding of important habitat attributes for Growling Grass Frogs in a variety of waterbodies including stream pools, swamps, quarry pits, farm dams and stormwater wetlands. Breakthrough research has identified factors influencing the severity of chytrid fungus disease in Growling Grass Frogs in the Merri Creek catchment. Much has also been learnt from observations of constructed waterbodies (stormwater wetlands and dedicated Growling Grass Frog wetlands), where in many instances populations of Growling Grass Frogs have declined after an initial period of occupancy.

The Department of Environment, Land, Water and Planning (DELWP) has prepared these *Growling Grass Frog Habitat Design Standards* to provide practical advice based on this updated information, to support both:

- the implementation of habitat protection measures outlined in the *Sub-regional Species Strategy for the Growling Grass Frog*; and
- investment in creating and enhancing habitat to compensate for the impacts of urban development.

The purpose of the standards is to provide guidance on protecting and creating the various types of habitat required to support metapopulations (multiple populations linked by migration) of Growling Grass Frogs over the long term. While the emphasis is on creating effective breeding wetlands, Growling Grass Frog conservation areas must also include habitats for foraging, sheltering over winter, migrating between populations and reducing the impact of chytrid fungus disease.

The standards update relevant guidance in the *Sub-regional Species Strategy for the Growling Grass Frog* and its supporting documents.

The standards do not provide design specifications for stormwater wetlands or other types of waterbodies such as lakes built for amenity purposes, but may provide useful advice in cases where the proponent wishes to provide Growling Grass Frog habitat as a secondary objective.

Within the Growling Grass Frog conservation areas established under the *Biodiversity Conservation Strategy for Melbourne's Growth Corridors*, DELWP will apply these standards to:

- the preparation of Conservation Area Concept Plans as part of Precinct Structure Plans;
- the assessment of infrastructure proposals within Growling Grass Frog conservation areas;
- the design and construction of Growling Grass Frog wetlands, and associated project specifications; and
- the review of completed Growling Grass Frog wetland projects.

The standards may be revised over time to incorporate research results and other new information including experience gained from constructing and enhancing Growling Grass Frog wetlands.



Large, warm and brackish wetlands provide refuge from chytrid fungus, which causes a deadly disease in many species including Growling Grass Frogs.

Photo by Geoff Heard, University of Melbourne

Growling Grass Frog habitat requirements

Growling Grass Frog ecology

Research and field observations in Victoria have identified habitat attributes associated with breeding, foraging, over-wintering, dispersal (including under roads) and chytrid disease control. Much of the following information comes from SWIFFT (accessed 2016).

The Growling Grass Frog was common and widespread across its range in south-eastern Australia, but declined quite suddenly from about 1990 and is now uncommon and threatened with extinction. This species displays “classical metapopulation” dynamics, in which networks of spatially discrete populations are connected by infrequent dispersal. Within these networks, populations are prone to extinction (for example when habitat becomes unsuitable), but these extinctions may be offset by colonisation of vacant habitat patches. The probabilities of extinction and colonisation vary among habitat patches and over time.

Extinction risks depend primarily on wetland size, permanence and cover of aquatic vegetation; the probability of a Growling Grass Frog population becoming extinct is lower in larger permanent wetlands with a high cover of aquatic vegetation, particularly submerged and floating species (Heard *et al.* 2010). The colonisation rate depends on the number, proximity (taking into account barriers such as roads) and size of neighbouring populations (Heard *et al.* 2013). A cluster of waterbodies within close proximity (maximum 700m but preferably much closer) allows frogs to move between sites as conditions change.

Growling Grass Frogs need permanent waterbodies with dense submergent and floating vegetation.

Photo by Geoff Heard, University of Melbourne

Growling Grass Frogs primarily need still or slow moving water with mats of floating and submerged plants. Favourable habitat features include abundant aquatic vegetation, rock piles around the margins and in the shallows, minimal tree canopy cover, moderate to low salinity, and water for at least six months of the year over the breeding season.

Growling Grass Frogs living in waterbodies with warmer water temperatures (up to 27 degrees) and moderate salinity have been found to have lower rates of chytrid fungus infection and mortality compared with those living in colder and fresher water in the nearby Merri Creek. Wetlands with warm, moderately salty water appear to act as refuges from chytrid fungus for the resident Growling Grass Frog populations, which therefore have a lower probability of extinction (Heard *et al.* 2014, Heard *et al.* 2015).

This species inhabits a wide variety of habitats from wet to very dry habitat at different times. Growling Grass Frogs eat a wide range of insects and even small lizards, fish, tadpoles and frogs. It is a ‘sit-and-wait’ predator. Growling Grass Frogs readily migrate from a drying site to a waterbody with suitable habitat, and usually move on rainy nights.

Tall emergent vegetation such as reeds and rushes gives protection to the adult frogs from predators. Submerged and floating attached vegetation protects eggs and tadpoles. Grass and shrub cover on the banks is also important for the emerging froglets to gain protection from predators. Short open vegetation structure allows Growling Grass Frogs to catch insects for food. During winter Growling Grass Frogs are largely inactive and shelter on the land under rocks, logs or thick vegetation, or in ground crevices. They are often a long way from waterbodies and sometimes shelter communally.





Growling Grass Frog basking on a rocky escarpment, Merri Creek.

Photo by Rob Valentic
www.gondwanareptileproductions.com

Growling Grass Frogs are active in the warmer months of the year (September to March) and like to bask in the sun on mild, sunny days. Like most frogs they usually call, feed and move around after dark.

Breeding begins in August when calling males begin being able to attract females, although females usually don't begin to lay eggs until October or November. Males will continue calling until about the end of March but females don't usually respond unless the season is very wet and warm. Eggs are laid in spring so the frogs need water that lasts over the summer for their tadpoles to develop. Females lay up to 4,000 eggs in foamy jelly rafts which sink into submerged vegetation within twelve hours. The hatching of tadpoles depends on water temperature, with 18 to 24 degrees Celsius being optimal. It may take up to five days in lower temperature conditions. The tadpoles hide in aquatic vegetation or move to deeper water if disturbed. The tadpole stage generally lasts several months and they may grow to 110 mm in total length. In Victoria, most tadpoles have emerged as frogs by the end of May.

Around Melbourne, there are various types of natural and created waterbodies that are known to frequently support Growling Grass Frog populations:

- quarry pits (from very large to very small) – often with little emergent vegetation but usually warm water in rocky and sheltered parts, and moderately saline due to groundwater seepage;
- large “turkey nest” (constructed with embankments) farm dams, some of which are drawn down over summer – usually little emergent vegetation but good submergent vegetation, and probably warmer water due to the shelter provided by embankments;
- large well-vegetated pools within streams – some in the basalt region are relatively saline due to groundwater seepage;
- large ephemeral swamps and other natural wetlands usually filled by overland rainwater flows and, in the basalt region, often relatively saline due to groundwater from shallow aquifers; and
- smaller ephemeral fresh water swamps that fill with rainwater or stream overflows in wet years.

Growling Grass Frogs also occupy some stormwater assets at times, particularly when submergent vegetation is available; however the dominance of emergent reeds and rushes in shallower treatment wetlands appears to preclude breeding. Stormwater systems usually also contain introduced fish that prey on eggs and tadpoles, particularly Eastern Gambusia (*Gambusia holbrooki*, also known as Mosquito Fish).

Growling Grass Frog are also recorded in smaller farm dams when conditions are suitable. The Dams to Habitat project (Nicholson *et al.* 2013) showed that excluding high density grazing and revegetating part of a farm dam created suitable conditions for breeding after only two years.

Threatening processes affecting Growling Grass Frogs

The following threatening processes are known to affect the Growling Grass Frog and/or its close relative (the Green and Golden Bell Frog *Litoria aurea*) in New South Wales:

- Permanent removal of habitat through constructing infrastructure, draining wetlands and filling quarry pits;
- Changed hydrological regimes including timing, frequency, volume and speed of flows, and lowering of groundwater through pumping of aquifers;
- Poor water quality including nutrients, turbidity (cloudiness caused by suspended particles), pesticides, detergents and heavy metals. High levels of nutrients cause eutrophication (dense growth of algae and plants) which results in lowered dissolved oxygen levels that do not support tadpoles (Hamer *et al.* 2004);
- Aquatic vegetation changes including scouring of vegetated pools, or overgrowth due to increased nutrient levels;
- Disease and death caused by the chytrid fungus *Batrachochytrium dendrobatidis*;
- Predation by introduced fish and yabbies;
- Loss of connectivity between habitats, including barriers posed by roads, other infrastructure or unsuitable habitat;
- Overshadowing of pools;
- Overly dense terrestrial vegetation adjacent to a wetland; and
- Grazing damage to wetland margins, including removal of vegetation and shelter, and reduction in water quality.

Metapopulation cluster design

Prioritisation modelling for the Masterplan showed that under a range of potential budget scenarios, creating clusters of wetlands that would support metapopulations (multiple populations connected by migration) of Growling Grass Frogs was a higher priority than improving connectivity between (inadequate) clusters. This reflects the need for robust metapopulations that will be viable over the long term, even if migration between metapopulations could be limited to wetter years.

The Masterplan identified high priority reaches for investment of Melbourne Strategic Assessment funds for the creation of Growling Grass Frog habitat in conservation areas along the Werribee River and Merri, Kororoit, Jacksons and Cardinia creeks. A cluster of off-stream wetlands will be created in each high priority reach to provide secure breeding habitat for a metapopulation, in addition to other existing habitat within the conservation area.

The spatial arrangement of created wetlands within a cluster should, wherever possible, maximise connectivity to facilitate gene flow and other population processes, especially colonisation and recolonisation after local extinctions. See Figure 1.

Enough wetlands should be provided in each cluster to allow for one or more to be dried out for management purposes in any given year without compromising metapopulation dynamics.

Cluster design standards

- Existing wetlands within conservation areas that support populations of Growling Grass Frog should be retained;
- Existing wetlands within conservation areas with the potential to support Growling Grass Frog populations over the long term should be enhanced to improve their suitability as habitat (for example by increasing their size, permanency and aquatic vegetation cover) where this will not impact on existing values (e.g. Seasonal Herbaceous Wetland);
- Clusters should contain at least 10 off-stream breeding wetlands, although smaller clusters may be acceptable in shorter reaches where there are fewer opportunities for wetland creation;
- The cluster total includes existing waterbodies to be enhanced or expanded, but does not include instream pools or billabongs that are likely to be frequently inundated because of the higher risk that these will become unsuitable for breeding;
- Wetlands should be no further apart than 200 - 300 m where possible, taking into account limitations in where wetlands can actually be constructed;
- At least three-quarters of the wetlands within a cluster should be permanent, or as close to permanent as practicable (excluding naturally seasonal wetlands); the critical period in which water is required is the breeding season which is generally between September and February;
- Each cluster should include a variety of wetland types to provide conditions suitable for different frog lifecycle stages (tadpoles, adults, breeding, egg-laying) and the control of chytrid fungus in adult Growling Grass Frogs;
- At least half of the wetlands within a cluster must be designed as "anti-chytrid" refuges with rocky basking sites and warm shallows, and preferably groundwater-fed; and
- All new wetlands must be constructed offline (that is, not within, or hydrologically connected to, a stream other than during exceptional floods).



Growling Grass Frogs bask on rocks to help combat chytrid fungus disease.

Photo by Geoff Heard, University of Melbourne

Figure 1 Growling Grass Frog conservation area overview





Growling Grass Frog wetland design

Wetland types

Growling Grass Frogs require a diversity of habitats in and around wetlands for the various stages of their lifecycle. These include access to areas of shallow water, which are often warmer due to solar radiation (and also support many invertebrate species that Growling Grass Frogs eat); steep drop-offs and areas of deeper water to escape predators; aquatic vegetation for shelter; and staging sites for calling and egg deposition (Pyke 2002). Rock piles near and in the wetland margin are likely to assist with chytrid fungus control by providing basking sites and warming the shallows. They also provide important shelter for Growling Grass Frogs in winter (Garnham *et al.* 2015). See Figure 2 and Figure 3.

Constructed wetlands will vary in type, with some quite natural in appearance but others more obviously artificial and resembling rocky quarry pits. For example, “anti-chytrid” wetlands have relatively warm and stable surface water temperatures, and preferably also moderate salinity. These will typically require areas of rock to warm the shallows, and embankments or shelterbelts to reduce the cooling effects of prevailing winds. Stormwater and other nutrient rich water sources are less optimal, as they may increase the risk of algal blooms and other plant overgrowth in these warm waterbodies. In contrast, “semi-natural” wetlands have more extensive areas of emergent vegetation around the perimeter.

Size

Constructed wetlands should be designed to be as large as is practicable taking into account the physical constraints of each site. Larger wetlands are more likely to support Growling Grass Frogs because the extinction risk for Growling Grass Frog populations increases when wetlands are not permanent (Heard and Scroggie 2009). Larger wetlands are more likely to be permanent and less likely to dry out in drought conditions. Larger wetlands also contain a larger quantity and diversity of food and shelter vegetation types favoured by Growling Grass Frogs (Heard *et al.* 2010).

Diverse vegetation planted in the shallows of a constructed wetland supports a variety of habitats and food species for Growling Grass Frogs.

Photo by Damien Cook, Rakali Ecological Consulting

Wetland size standards

- The surface area of most new wetlands in a cluster must be at least 0.3 ha where space allows. Where space is limited, the surface area of wetlands can be reduced, but not below 0.15 ha. In all cases the submergent zone must be at least 0.1 ha in area; and
- If possible, at least one wetland in a cluster should be large (greater than 0.7 ha); in some cases this could be achieved by merging two standard (medium) sized wetlands.

Shape

Wetlands should generally be shaped to maximise the area of deep water for submerged and floating vegetation, while providing extensive vegetated and/or rocky margins. Wetlands must not be too narrow as this will reduce the capacity to achieve the required depths.

Wetland shape standards

- Wetlands must be wide enough to efficiently provide the required area of deep water for submerged vegetation; and
- Islands within the wetland are not permitted, as they are likely to encourage excessive numbers of waterbirds which may increase predation pressure and contaminate the shallows with concentrated droppings.





Dense submergent vegetation supports Growling Grass Frogs in many ways, including by providing tadpoles with some protection from predatory fish.

Photo by Daniel Gilmore, Biosis Pty Ltd

Depth, gradients and water level variation

Water depth is a particularly important consideration because it determines aquatic vegetation structure and composition – and many wetlands constructed in the past have been too shallow to sustain the submerged vegetation that Growling Grass Frogs require.

Usually, at least half of the wetland area must be deep water supporting a dense cover of submergent and floating vegetation, which is a critical component of successful Growling Grass Frog habitat. Maintaining areas of deep water within a wetland prevents the domination of the waterbody by emergent aquatic plant species such as Common Reed (*Phragmites australis*) and bulrushes (*Typha* spp.) which tend to choke out shallow wetlands.

Wetlands also need to have shallow areas supporting emergent vegetation, which is an important component of Growling Grass Frog habitat. Shallow areas of water are also warmer due to solar radiation, and warm water accelerates vegetation growth as well as tadpole development. Warm water probably also increases the productivity of wetlands, which in turn provides additional food resources such as invertebrates for Growling Grass Frog populations. Most importantly, warmer water has been shown to suppress chytrid fungus (Heard *et al.* 2015). At least 20 per cent of the perimeter of constructed wetlands should be rocky, and preferably more in “anti-chytrid” wetlands where excavated rock is freely available.

The emergent vegetation zone must incorporate a littoral zone that is subject to fluctuating water levels due to seasonal evaporation rates and rainfall variation. Fluctuating water levels within wetlands are important for nutrient cycling and the promotion of growth in some aquatic plants (Romanowski 1998). This zone is used by Growling Grass Frogs to ambush prey on bare soil/exposed mud and to perch on rocks and groundcover vegetation near the water’s edge.

Water depth and gradient standards

- All wetlands must incorporate a deep water submergent vegetation zone, constituting a minimum of 50 per cent and preferably 60–70 per cent of the total wetland surface area at normal water level;
- The water depth in the submergent zone must be maintained at greater than 1.5 m. Wetlands with greater maximum depths are desirable and should be constructed if feasible;
- The emergent vegetation zone should occupy approximately 30–40 per cent of the wetland area, and should include a littoral zone with fluctuating water levels (for example between normal water level and the summer drawdown level); and
- A variety of slopes must be incorporated into the design of the banks, including steep drop-offs wherever this can be accommodated within land managers’ safety standards.



Shallow waterbodies (in foreground) with raised nutrient levels become dominated by tall reeds and rushes – not good breeding habitat for Growling Grass Frogs.

Photo by Kathy Preece

Hydroperiod

Research has demonstrated that extinction risk for Growling Grass Frog populations is lower in wetlands that display a permanent hydroperiod (Heard *et al.* 2010). Wetlands should be designed to have a permanent hydroperiod or one that is as long as practicable given constraints associated with wetland size and water supply. Timing is also important – wetlands need to contain water during the species' breeding period, which (around Melbourne) is generally between September and February. Tadpoles develop over several months during spring and summer.

Wetland hydroperiod standards

- At least three-quarters of the wetlands in a cluster should have a permanent hydroperiod, and as many as possible should hold water over the breeding season (September to February). Ideally water levels should draw down naturally over late summer and autumn;
- Semi-permanent and ephemeral wetlands may be acceptable where there is limited capacity to provide a permanent wetland or if there is a specific requirement (for example to maintain a natural Seasonal Herbaceous Wetland); and
- New wetlands should be designed to allow them to be periodically dried out for management and maintenance purposes (for example the control of predatory fish).

Wetland lining and substrate for vegetation

A clay liner is generally required to prevent leakage through the floor of a permanent wetland. Topsoil set aside during excavation can often be used to provide the substrate in which aquatic vegetation can be established.

The choice of substrate and its depth will influence the establishment and growth of aquatic plants. Substrate choice should aim to reduce turbidity to the greatest extent possible. Rocky substrates are unsuitable as they inhibit plant growth.

Wetland lining and substrate standards

- The wetland must be lined (usually with clay rather than synthetic material) to prevent leakage; and
- A layer of soil must be placed over the liner. It must be suitable for establishment and long-term persistence of aquatic plants, and must not result in high turbidity after wetland establishment. Clay soil is acceptable for use as a substrate.



Rocky edges help maintain warmer water temperatures, which disadvantages the chytrid fungus.

Photo by Peter Robertson, Wildlife Profiles Pty Ltd

Thermal properties

Growling Grass Frogs are susceptible to infection by the amphibian chytrid fungus *Batrachochytrium dendrobatidis*, which causes the disease chytridiomycosis. This disease has been implicated in the decline in populations of frogs from the group of closely related species, especially those in inland and high altitude sites (Mahony *et al.* 2013). The disease is now common in Growling Grass Frog populations around Melbourne (Heard *et al.* 2014).

Recent research has highlighted the influence of water temperature within wetlands on the prevalence and intensity of chytrid infection in Growling Grass Frog populations (Heard *et al.* 2014). Growling Grass Frog populations inhabiting warmer wetlands show lower chytrid infection rates, and individual infected frogs have a lower intensity of the disease (Heard *et al.* 2014). Warm, moderately saline waterbodies have been shown to act as refuges for Growling Grass Frogs against the chytrid fungus (Heard *et al.* 2015).

Most Growling Grass Frog wetlands should therefore be designed to achieve "anti-chytrid" thermal properties in at least 20 per cent of their perimeter, and preferably more where excavated rock is freely available. Designs should include rock piles in the shallows to act as heat banks which will provide areas of elevated water temperature. Most of the shallows should be free of shading from tall and dense emergent aquatic plants (for example *Typha* spp.) and shrubs and trees.

Thermal properties standards

- Wetlands must be large and deep to provide thermal inertia;
- Wetlands must incorporate an extensive, shallow, permanently inundated emergent zone where water temperatures will be elevated due to the heat of the sun;
- All wetlands should incorporate jumbled piles of rocks around at least 20 per cent of the margin, extending into the wetland at least one metre from normal water level;
- "Anti-chytrid" wetlands in the basalt region (where excavated material can be used on site rather than paying for disposal offsite) should incorporate rocks around 50 per cent of the wetland margin if within budget; and
- Embankments to cut prevailing winds may be useful, and can be constructed from excavated material.



Growling Grass Frog populations in shady cold pools have a higher incidence of chytrid fungus infection than do populations in warm waters.

Photo by Geoff Heard, University of Melbourne

Water source

The water source used to fill and maintain water levels within Growling Grass Frog wetlands will influence the suitability of the wetland habitat. For example, a highly turbid water source will cause sedimentation of the wetland and retard the growth of submergent plant species by reducing light penetration.

Potential water sources for Growling Grass Frog wetlands include:

- groundwater;
- potable water;
- rainwater (surface runoff from overland or from roofs);
- stream water;
- recycled water; and
- treated stormwater.

There are advantages and disadvantages to each water source, such as availability, cost to supply, feasibility, relative suitability (salinity or nutrient loads) and potential impacts to nearby habitat (for example harvesting water from streams may reduce the quality of instream habitat).

The following preferences have not taken into consideration the relative cost or feasibility of each option as these will vary from case to case.

Generally, groundwater is the preferred source of water for at least half of the enhanced and new wetlands in each cluster.

Stormwater treated to current “best practice” standards may still contain levels of nutrients that promote a proliferation of undesirable plants or algal blooms, particularly in the warmer waters required in “anti-chytrid” wetlands.

There may be situations where it is appropriate for Growling Grass Frog wetlands to harvest treated stormwater, noting that the primary function, maintenance and operation of the drainage asset must not be compromised. A decision to do this must consider:

- any site or design constraints on the stormwater treatment wetland that may mean that it could not be designed to meet current industry “best practice” water quality standards;
- that the water authority cannot provide a guarantee regarding the quantity and quality of treated stormwater; and
- any risks associated with security of supply and whether stormwater is fit for purpose.

Wetland water source standards

- Groundwater is generally preferred, where feasible; and
- Use the best possible source of water in response to each set of circumstances, using Table 1 as a guide.

Table 1 Water sources for Growling Grass Frog wetlands

Priority	Source	Advantages	Disadvantages
1	Groundwater	<ul style="list-style-type: none"> Groundwater in many of the Growling Grass Frog conservation areas is moderately saline, which has been shown to reduce chytrid infection; and Free from predatory fish. 	<ul style="list-style-type: none"> May require construction and/or maintenance of bore; May be too saline in some instances; and Salinity may build up over time.
2	Rainwater (surface runoff)	<ul style="list-style-type: none"> Contains relatively few contaminants if filtered through soil in local catchment; and Free from predatory fish. 	<ul style="list-style-type: none"> Limited by rainfall and catchment size; May be turbid; and Relatively fresh (non-saline) so may be less effective for reducing the incidence of chytrid.
3	Stream water	<ul style="list-style-type: none"> Many of the streams in the conservation areas supporting breeding populations of Growling Grass Frogs are moderately saline and have chytrid inhibiting properties. 	<ul style="list-style-type: none"> Likely to contain predatory fish (can be filtered out); May be turbid and contain unacceptable levels of nutrients and pollutants; and Water quality is likely to deteriorate as urbanisation of the catchment intensifies.
4	Treated stormwater	<ul style="list-style-type: none"> Reliable water source; Treated to ensure water quality meets best practice standards; and Readily available. 	<ul style="list-style-type: none"> Likely to contain predatory fish (can be filtered out); May be high in nutrients and contaminants; and Relatively fresh (non-saline) so may be less effective for reducing the incidence of chytrid.
5	Rainwater (from roofs)	<ul style="list-style-type: none"> Free from predatory fish; and May be high quality in some cases. 	<ul style="list-style-type: none"> Reliant on local rainfall; Reliant on suitable roof catchment nearby; Relatively fresh (non-saline) so may be less effective for reducing the incidence of chytrid; and May contain contaminants/nutrients from bird droppings.
6	Potable water	<ul style="list-style-type: none"> Clean source of water with low levels of nutrients; and Free from predatory fish. 	<ul style="list-style-type: none"> Unlikely to be available for use for Growling Grass Frog wetlands; and Fresh (non-saline) so may be less effective for reducing the incidence of chytrid.
7	Recycled water	<ul style="list-style-type: none"> Reliable water source; and Free of predatory fish. 	<ul style="list-style-type: none"> Contains high levels of nitrogen.





Growling Grass Frogs forage for insects on short mown grass – including lawns – adjacent to wetlands.

Photo by Jason Sonneman, DesignFlow Pty Ltd

Water quality

There is relatively little known about the chemical attributes of water in wetlands inhabited by Growling Grass Frogs. It appears that the species inhabits waterbodies displaying a broad range of water quality values across its range, even occupying sediment ponds that receive untreated stormwater, and also lagoons at the Western Treatment Plant in Werribee. However extended exposure to pollutants may impact on Growling Grass Frogs' health, breeding success and resilience to disease and changing climatic conditions over the long term.

Recent research has shown that salinity is important due to the influence it exerts on Growling Grass Frogs' susceptibility to chytrid fungus infection. Research by Heard *et al.* (2014) showed that the prevalence and intensity of chytrid infection was lower in wetlands with higher salinities (as measured by electrical conductivity) and that moderately salty wetlands can act as refuges from chytrid fungus (Stockwell *et al.* 2015; Heard *et al.* 2015). Moderately saline groundwater is therefore the preferred water source for Growling Grass Frog wetlands. Salinity levels will need to be tested to ensure that they are within the range tolerated by the species, and that they do not increase over time.

For wetlands fed by treated stormwater, treatment must remove gross pollutants and filter out suspended solids, excess nutrients, heavy metals and chemical pollutants prior to that water entering the Growling Grass Frog wetland.

Further research including analysis of existing water quality and sediment contaminant data is required to determine which water quality attributes are most likely to negatively affect Growling Grass Frogs, and appropriate thresholds for these substances – noting that some are likely to accumulate in the sediment layer over time.

Water quality standards

- The water quality standards in Table 2 should be applied.



Plantings of aquatic herbaceous species must be netted for a year or two to protect them from waterbirds such as swans and swamphens.

Photo by Damien Cook, Rakali Ecological Consulting

Table 2 Water quality standards for Growling Grass Frog wetlands

Water quality parameter	Target value
Gross pollutants	To be determined
Dissolved Oxygen (mg/L)	To be determined
Total Nitrogen (mg/L)	< 1.0 (maximum from SEPP Waters of Victoria 2001) – to be confirmed
Ammonia (mg/L)	< 0.01 (N-1) as NH ₄ ⁺ (ANZECC 2000)
Total Phosphorous (mg/L)	< 0.1 (maximum from SEPP Waters of Victoria 2001) – to be confirmed
Chlorine (mg/L)	To be determined
pH	6.0 - 8.5 (SEPP Waters of Victoria 2001)
E. coli (orgs/100 ml)	Primary Contact < 150 Secondary Contact < 1000
Organic toxicants	There numerous organic toxicants ranging from straight hydrocarbons to various pesticides containing organic compounds. For endocrine disruption compounds like oestradiol (synthetic oestrogen) there are no ranges or triggers under SEPP or ANZECC guidelines
Metals	Minimise soluble and total metals
Salinity (µS/cm)	Moderately saline, up to 5000 µS/cm (Heard <i>et al.</i> 2014). Salinity can have negative effects on both the probability and intensity of chytrid infections (Heard <i>et al.</i> 2014). However, if salinity is too high, it is detrimental to frogs and tadpoles and will limit vegetation growth.
Turbidity (NTU's)	< 40

Aquatic vegetation

The Growling Grass Frog relies heavily on aquatic vegetation, particularly floating and submergent lifeforms (Heard *et al.* 2008), and the cover of this vegetation is a strong predictor of wetland occupancy (Heard 2010).

Wetlands should be designed and constructed in such a way that they support a high cover of aquatic vegetation, particularly floating and submergent species in deeper water that cannot be overgrown by dense reeds and rushes. Existing wetlands could also be enhanced to support a higher cover and diversity of the floating and submergent species.

All Growling Grass Frog wetlands must incorporate emergent, submergent and floating species found in Appendix 1. These include species that should be relatively easy to cultivate and shown to do well in such environments. They should also be indigenous to the local area (to ensure they do not become an environmental weed) and where possible of local provenance as locally sourced plants are more likely to do well.

Aquatic vegetation standards

- It is assumed that initial plantings will spread quickly if wetland conditions are suitable, so the whole wetland does not need to be planted out. For example, submergent species would normally be planted on the slopes of the wetland, rather than at the maximum depth. The proportion of a wetland to be planted will be determined during the project planning phase;
- Planting density must be such that it results in the establishment of a dense (target 50 per cent) cover of submergent/floating vegetation in the deep water zone and patches of emergent vegetation within several years. As a guide, planting densities to create patches of emergent vegetation are generally 4 – 6 plants per square metre. Planting densities for patches of submergent vegetation can be lower;
- A diversity of vegetation is highly desirable;
- Species to be planted in Growling Grass Frog wetlands must be selected from those shown in Appendix 1, taking account of local water quality conditions (brackish wetlands should be planted out with species adapted to growing in moderately salty conditions);
- In the deep water zone, submergent/floating species must include Water Ribbons (*Cycnogeton procerum* - formerly *Triglochin procerum*) and species from the genus *Potamogeton* – or if the water is brackish, Fennel Pondweed (*Stuckenia pectinata* - formerly *Potamogeton pectinatus*);
- Exotic species must not be used; and
- Common Reed (*Phragmites australis*) and bulrushes (*Typha* spp.) do not need to be planted as they are likely to establish naturally over time.

Predators

Several native and introduced fish are known predators of the eggs and tadpoles of frogs (Gillespie and Hero 1999). For example, the introduced Eastern Gambusia (*Gambusia holbrooki* also known as Mosquito Fish) has been shown to consume eggs and tadpoles of the Growling Grass Frog and its close relative the Green and Golden Bell Frog *Litoria aurea* in laboratory experiments. Heard (2010) demonstrated that the occurrence of predatory fish is negatively related to wetland occupancy by Growling Grass Frogs.

However, Growling Grass Frogs are known to inhabit and breed in a number of wetlands around Melbourne containing populations of Eastern Gambusia, so the predators' presence does not necessarily preclude the persistence of Growling Grass Frogs. Heard *et al.* (2010) suspected that the protective effect of aquatic vegetation is important in reducing predation on Growling Grass Frog eggs and tadpoles by fishes and thus allowing the co-existence of Growling Grass Frog populations.

Recent research has also suggested that in some instances yabbies may be an important predator of Growling Grass Frog eggs and tadpoles (Koehler *et al.* 2015).

Other known predators of tadpoles (e.g. aquatic invertebrates, birds, turtles) are also likely to prey upon Growling Grass Frog tadpoles in constructed wetlands.

Where possible, wetlands should be designed to reduce the likelihood that they will be colonised by fish and yabbies. This can be achieved by locating wetlands so that they do not receive inundation from nearby streams (a source of fish) or are constructed to include fish exclusion devices (for example gravel and sand filters) if their main water source is from stormwater treatment wetlands. Where this is not possible, wetlands should be designed so that they can be periodically dried out for short periods of time to kill predators.

Predator control standards

- All newly constructed wetlands must be offline. Wetlands constructed within a floodplain should incorporate bund walls to reduce the frequency of fish incursion; and
- Incorporate a fish exclusion filter in the hydraulic connection system between the source of treated stormwater or creek/river water and the Growling Grass Frog wetland.

Also see standards for:

- depth – deep water may assist with predator avoidance (especially predatory birds) and some predatory fish species such as Eastern Gambusia prefer to aggregate in shallow parts of the wetland where temperatures are higher;
- hydroperiod – dry wetlands out as required to remove or control populations of fish, yabbies and other predators; and
- aquatic vegetation – provides refuge for tadpoles.

Terrestrial habitat

The terrestrial area adjacent to wetlands and streams is important habitat for Growling Grass Frogs, which use it for dispersal, foraging and shelter during periods of inactivity. Terrestrial refuge sites such as soil cracks, vegetation fringing wetlands and rock piles are important habitat features associated with wetlands inhabited by Growling Grass Frogs (Heard *et al.* 2008).

Growling Grass Frogs prefer relatively open terrestrial habitats to facilitate foraging and movement (Heard *et al.* 2008). The vegetation structure is more important than the plant species. The most important terrestrial area for Growling Grass Frogs is land up to a distance of approximately 100 m from the normal water level (Heard *et al.* 2010). In Areas of Strategic Importance mapping (DELWP 2017) this is represented with blue, purple and green shading.

Adequate terrestrial habitat must be provided around Growling Grass Frog wetlands and along streams likely to be used by the species. Figure 1 shows a typical landscape layout.

Terrestrial habitat standards

- A minimum 50 m buffer from development must surround each wetland, in which major infrastructure such as roads, car parks, and buildings should be avoided (unless the wetland is constructed closer than 50 m to the conservation area boundary because of space constraints);
- Shared use paths, other minor infrastructure for passive recreation and stormwater assets must not be constructed closer than 30 m from the normal water level of a breeding wetland;
- Approximately 50 per cent of the area within 10 m of the wetland's normal water level must be designed to be maintained as low, grassy vegetation up to 10 cm in height;
- Where tussock-forming grasses and sedges are used in the zone that is within 10 m of normal water level, planting density should allow for no greater than 20 per cent cover when mature;
- Mulch must not be used within 50 m of a wetland;
- Shrubs must not be planted within 10 m of the wetland's normal water level;
- Rock piles at least one metre deep must be constructed adjacent to the wetland margin using a variety of rock sizes between 10 cm and one metre in diameter;
- Where possible, the area between 10 m and up to 100 m (where space is available) from the wetland should be designed to be maintained primarily as short, mown grass with an open structure (for example 20 per cent cover);
- Tree cover within 100 m of a wetland should not exceed 10 per cent;
- Shrub cover within 100 m of a wetland should not exceed 10 per cent;
- A patchy arrangement of denser plantings of tussock-forming species is encouraged to maintain some potential terrestrial shelter sites;
- Low, grassy vegetation areas do not need to be native vegetation (mown pasture grasses and even lawn are acceptable); and
- Invasive plant species must not be used anywhere within the terrestrial habitat zone.

Short, open grassy vegetation provides foraging habitat for Growling Grass Frogs.

Photo by Digby Richardson, Melbourne Water



Figure 2 Growing Grass Frog habitat design

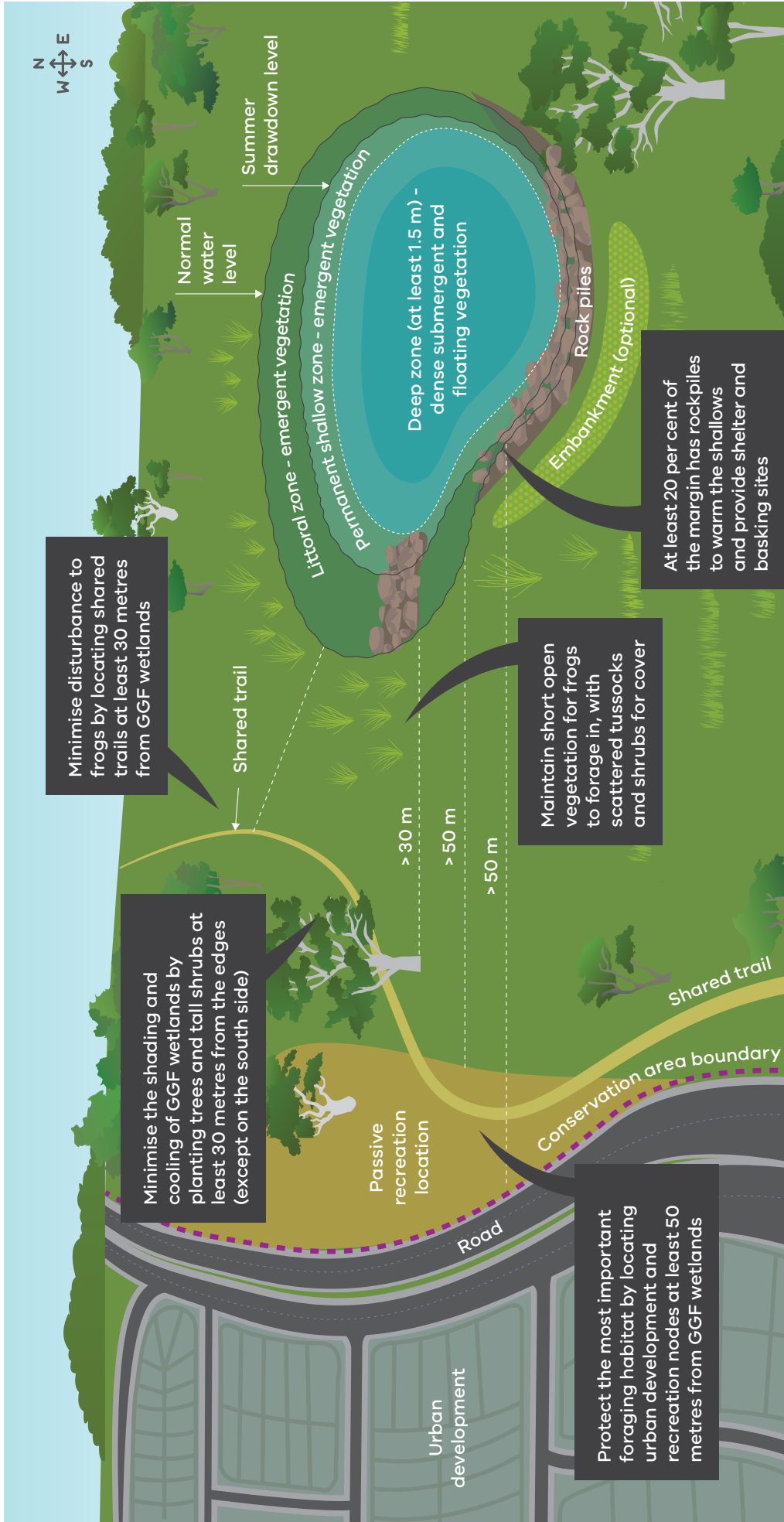
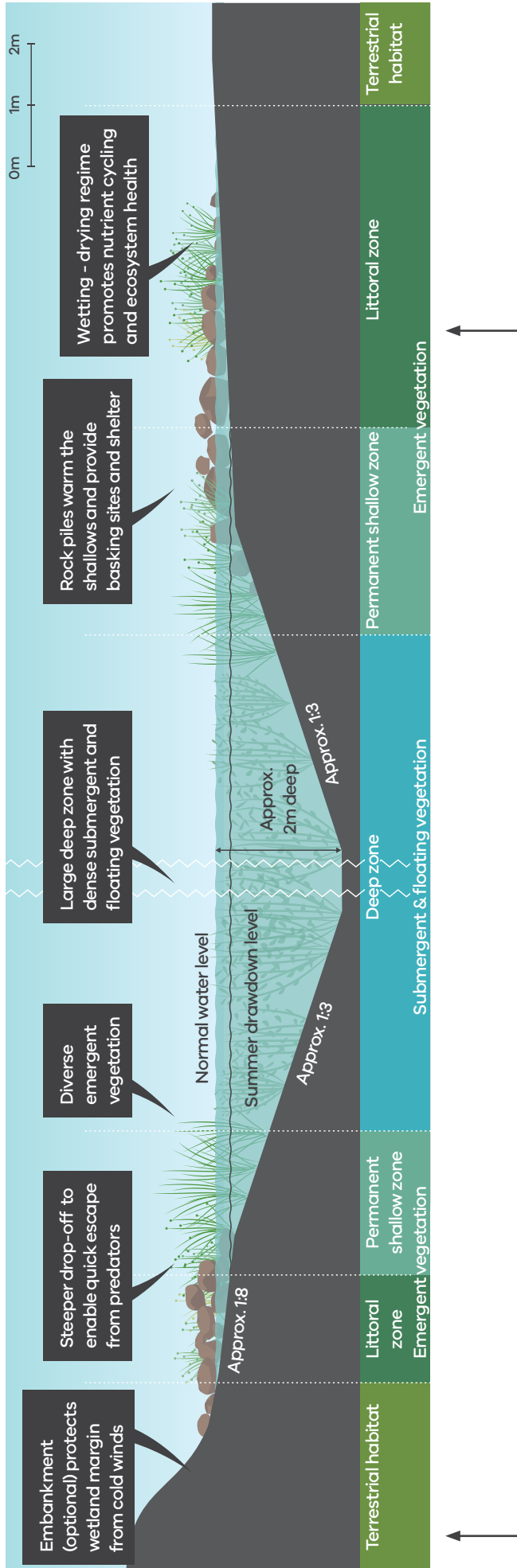


Figure 3 Growing Grass Frog wetland attributes



Embankment.
Photo by Nino Polon, Melbourne Water



Jumbled rock piles.
Photo by Peter Robertson, Wildlife Profiles Pty Ltd

Glossary

brackish	Moderately salty water or wetland, with a salinity level between that of fresh water and seawater.
buffer	An area of land surrounding a habitat feature for Growling Grass Frogs.
chytrid fungus	<i>Batrachochytrium dendrobatidis</i> , a parasitic fungus of amphibians. It spreads within water and moist environments.
chytridiomycosis	An infectious disease of amphibians, caused by chytrid fungus.
colonisation	The process by which a species establishes a new population in an unoccupied environment.
connectivity	The degree to which a corridor, network or matrix of wetlands is connected for Growling Grass Frogs. In practice, this usually refers to the capacity for physical movement, or gene-flow for the species, through the landscape.
dispersal	The movement of Growling Grass Frogs through the landscape. Especially relates to movements between one key habitat and another, such as between waterbodies and between aquatic and terrestrial micro-environments.
drawdown period	The period when wetlands dry out, usually summer as a result of high evaporation rates and reduced rainfall.
emergent vegetation	Aquatic plants that are rooted below the water surface and with foliage emergent above the water-surface (Heard <i>et al.</i> 2010).
emergent zone	The area of up to about one metre deep around the margin of a wetland supporting mainly emergent aquatic plants. Comprised of a permanently inundated zone and a littoral zone that is subject to periodic wetting and drying.
ephemeral	see hydroperiod
exotic	Not native to an area
floating vegetation	Rooted or unrooted aquatic plants (macrophytes or algae) with foliage floating on the water's surface (Heard <i>et al.</i> 2010).
floodplain	An area of low-lying ground adjacent to a river or stream, formed mainly of river sediments and subject to periodic flooding.
gene exchange	The exchange of genes between populations or lineages that occurs via sexual reproduction. Genetic diversity, important for maintaining fitness of populations, is facilitated by gene exchange.
gradient	In this context, the slope of the floor/bank of a waterbody.
hydroperiod	The length of time or season in which a wetland holds standing water. Definitions of hydroperiod (from Table 1 Heard <i>et al.</i> 2010 p. 5): <ul style="list-style-type: none"> • Ephemeral - Fills and dries out annually with average rainfall. • Semi-permanent - Fills and dries out annually, or at some other interval, according to rainfall. • Permanent – Never dries out, regardless of rainfall.
indigenous	Originating or occurring naturally in a particular place.
lifeform	In this context, the physical characters of different types of aquatic vegetation.
littoral zone	The area of a wetland that is subject to regular wetting and drying as water levels change, usually seasonally.
macrophyte	An aquatic plant that is visible to the naked eye.
metapopulation	A discrete cluster of Growling Grass Frog populations that interact with one another through dispersal.
normal water level	The top of a permanent waterbody.

nutrient cycling	The essential movement and exchange of organic and inorganic matter through an ecosystem.
offline wetland	A wetland that is not connected hydrologically to an existing stream or drainage network
online wetland	A wetland that is connected hydrologically to an existing stream or drainage network
pervious	Permeable to water.
recolonisation	The process by which a species re-establishes in a vacant, but formerly inhabited area.
refugia	At the wetland level, refugia are microenvironments to which Growling Grass Frogs retreat during periods of inactivity and to survive unfavourable conditions. These include locations used during winter and in particularly hot and dry periods. At the landscape level, warm and saline water bodies act as environmental refuges from chytrid fungus.
salinity	The concentration of salt in water.
stormwater	Surface water in abnormal quantity resulting from heavy rainfall.
submergent vegetation	Aquatic plants rooted and with foliage below the water-surface (Heard <i>et al.</i> 2010).
submergent zone	The area at least one metre deep supporting submerged and floating aquatic plants.
substrate	The surface or material on or from which an organism lives, grows, or obtains its nourishment.
surface runoff	The flow of water that occurs when stormwater, or water from other sources, flows over the earth's surface.
terrestrial habitat	Habitat for Growling Grass Frogs that is located away from the wetland margin. This may include areas well away from open water in which they forage, shelter (for example over winter) or move between waterbodies.
turbidity	A measure of water clarity i.e. how much the material suspended in water impedes the passage of light through the water.



Growling Grass Frog (*Litoria raniformis*).
Photo by Geoff Heard, University of Melbourne

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Appendix: Aquatic plants to be used in Growling Grass Frog wetlands

This list of aquatic plants is to be used when establishing vegetation in Growling Grass Frog wetlands. They have been selected based on their value as Growling Grass habitat, ease of cultivation and availability.

Botanical name (from VICFLORA vicflora.rbg.vic.gov.au)	Common name	Lifeform*	Notes
<i>Alisma plantago-aquatica</i>	Water Plantain	E	Suitable for use throughout Melbourne
<i>Baumea arthrophylla</i>	Fine Twig-sedge	E	Suitable for use throughout Melbourne
<i>Baumea articulata</i>	Jointed Twig-sedge	E	Suitable for use throughout Melbourne
<i>Baumea juncea</i>	Bare Twig-sedge	E	Suitable for use throughout Melbourne. Slow growing but can be grown by division
<i>Bolboschoenus caldwellii</i>	Salt Club-rush	E	Suitable for use throughout Melbourne. Fast growing species suitable for brackish sites.
<i>Carex appressa</i>	Tall Sedge	E	Better suited to the east of Melbourne
<i>Carex tereticaulis</i>	Basket Sedge	E	More common in Melbourne's west
<i>Crassula helmsii</i>	Swamp Crassula	E, S	Suitable for use throughout Melbourne. Fast growing species.
<i>Cycnogeton procerum</i> (formerly <i>Triglochin procerum</i>)	Common Water-ribbons	E, F, S	Suitable for use throughout Melbourne
<i>Eleocharis acuta</i>	Common Spike-sedge	E	Suitable for use throughout Melbourne
<i>Eleocharis sphacelata</i>	Tall Spike-sedge	E	Suitable for use throughout Melbourne
<i>Juncus amabilis</i>	Hollow Rush	E	Suitable for use throughout Melbourne
<i>Juncus flavidus</i>	Golden Rush	E	Suitable for use throughout Melbourne
<i>Juncus semisolidus</i>	Plains Rush	E	Suitable for use throughout Melbourne
<i>Marsilea drummondii</i>	Common Nardoo	E	Suitable for use throughout Melbourne

* E – Emergent, F – Floating, S – Submergent

Botanical name (from VICFLORA vicflora.rbg.vic.gov.au)	Common name	Lifeform*	Notes
<i>Myriophyllum caput-medusae</i>	Coarse Water-milfoil	E, S	Suitable for use throughout Melbourne. Can grow in quite deep water
<i>Myriophyllum crispatum</i>	Upright Water-milfoil	E, F, S	Suitable for use throughout Melbourne
<i>Myriophyllum salsugineum</i>	Lake Water-milfoil	E, S	Suitable for use throughout Melbourne. Grows best in brackish water
<i>Myriophyllum simulans</i>	Amphibious Water-milfoil	E, F, S	Suitable for use throughout Melbourne
<i>Myriophyllum verrucosum</i>	Red Water-milfoil	E, S	Suitable for use throughout Melbourne
<i>Ornduffia</i> (formerly <i>Villarsia reniformis</i>)	Running Marsh-flower	E, F	Suitable for south-east Melbourne
<i>Ottelia ovalifolia</i> subsp. <i>ovalifolia</i>	Swamp Lily	E, S	Suitable for use throughout Melbourne. Only suitable for fresh water environments
<i>Persicaria decipiens</i>	Slender Knotweed	E	Suitable for use throughout Melbourne
<i>Potamogeton cheesemanii</i>	Red Pondweed	S	Suitable for use throughout Melbourne
<i>Potamogeton crispus</i>	Curly Pondweed	S	Suitable for use throughout Melbourne
<i>Potamogeton ochreatus</i>	Blunt Pondweed	S	Suitable for use throughout Melbourne
<i>Potamogeton pectinatus</i> – see <i>Stuckenia pectinata</i>			
<i>Ruppia megacarpa</i>	Large-fruit Tassel	S, F	Suitable for use throughout Melbourne. Grows best in brackish water
<i>Ruppia polycarpa</i>	Many-fruit Tassel	S, F	Suitable for use throughout Melbourne. Grows best in brackish water
<i>Stuckenia pectinata</i>	Fennel Pondweed	S	Suitable for use throughout Melbourne. Grows best in brackish water
<i>Triglochin procera</i> – see <i>Cycnogeton procerum</i>			
<i>Utricularia australis</i>	Yellow Bladderwort	F, S	Suitable for use throughout Melbourne
<i>Vallisneria australis</i>	Eel Grass	S	Suitable for use throughout Melbourne

* E – Emergent, F – Floating, S – Submergent

