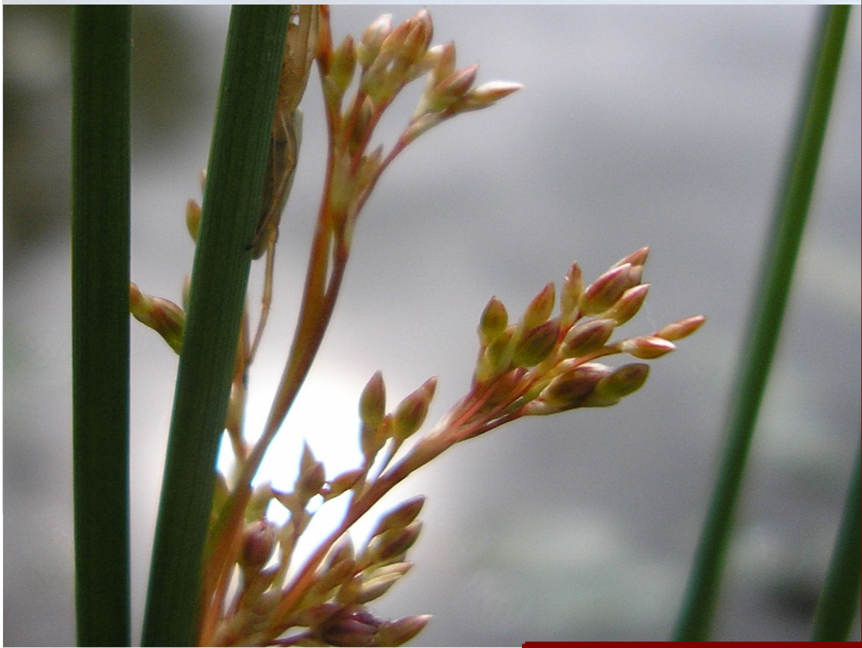
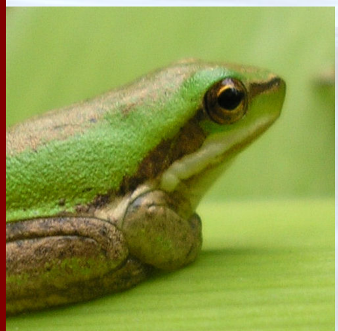
NEPEAN RIVER PUMP & PIPELINE
Investigation into Aquatic Weed Transfer
Control & Water Quality





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Project Identification

Project Name:

Nepean River Pump & Pipeline

Investigation into Aquatic Weed Transfer Control

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Penrith

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1 Introduction

1.1 Purpose and Objectives

This report has been prepared for Maunsell Australia Pty Ltd to investigate aquatic weed transfer control and water quality measures for the proposed Nepean River Pump and Pipeline. The objectives of this report are to:

- Review of Concept Design of the Nepean River Pump and Pipeline in light of reducing the potential for weed transfer between the river and Penrith Lakes and provide advice and recommendations on a multi-barrier approach to weed transfer control; and

- Provide advice and recommendations regarding nutrients and an optional quarantine lake.

1.2 Background

Penrith Lakes Development Corporation (PLDC) has engaged Maunsell Australia to design the pump and pipeline system to deliver water from the river to meet water requirements of Penrith Lakes.

Maunsell Australia has in turn commissioned Australian Wetlands to review the concept design for the proposed Nepean River Pump and Pipeline scheme in light of controlling and mitigating the potential transfer of weeds from the Nepean River into Penrith Lakes. The objective of the pump and pipeline scheme is to deliver water from the river to initially fill the lakes and to maintain the required volumes to sustain the lakes in the long term.

A set of pumping rules have been developed to prevent adverse impacts on river ecology as a result of water extraction, whilst meeting the requirements of the lakes. These are:

- Pump flow rate 1.0m^3/s;

- Pumping to start when flow reaches 500ML/day over Penrith weir; and

- Upper pumping limit to be approximately 2,500 ML/day.

These rules have been developed to meet the following criteria (as identified by Maunsell):

- Meet the water level criteria for the lakes;

- Limit pumping to period of appropriate water quality in the river to meet Penrith Lakes water quality objectives;

- Minimise the impact on the Nepean River's ecology through low flow pumping rules; and

- Minimise the impact on downstream users.

The pump system will consist of twin submersible pumps located in a wet well in a pumping station constructed in the bank of the Nepean River and controlled by the control building located above the flood line in the Weir Reserve. The system will be fully automatic with monitoring and overriding control undertaken from the PLDC offices (Maunsell, 2005).

The design included the selection of the proposed route of the pipeline from the Nepean River to Penrith Lakes. The preferred option (Option 3, Figure 1) was chosen to minimise impacts on the existing lake and quarry operations and for water quality control and economic reasons. The Option 3 alignment runs from Weir Reserve, crosses Castlereagh Road and then runs parallel to Castlereagh Road temporarily discharging into Lake A. Water will be permanently discharged to the Quarantine Lake (an extension to the Warm Up Lake) once it is constructed.

2 Site Location

2.1 Site Location

Penrith Lakes and the Nepean River are located within the Penrith Valley at the foot of the Blue Mountains. The Penrith Lakes Scheme covers an area of 2,000 ha of which 700 ha is made up of five major recreational lakes and a series of smaller lakes. The Nepean River Pump and Pipeline proposal will draw water from near Penrith Weir and convey water to the Penrith Lakes Scheme north of the river. See Figure 1 below.

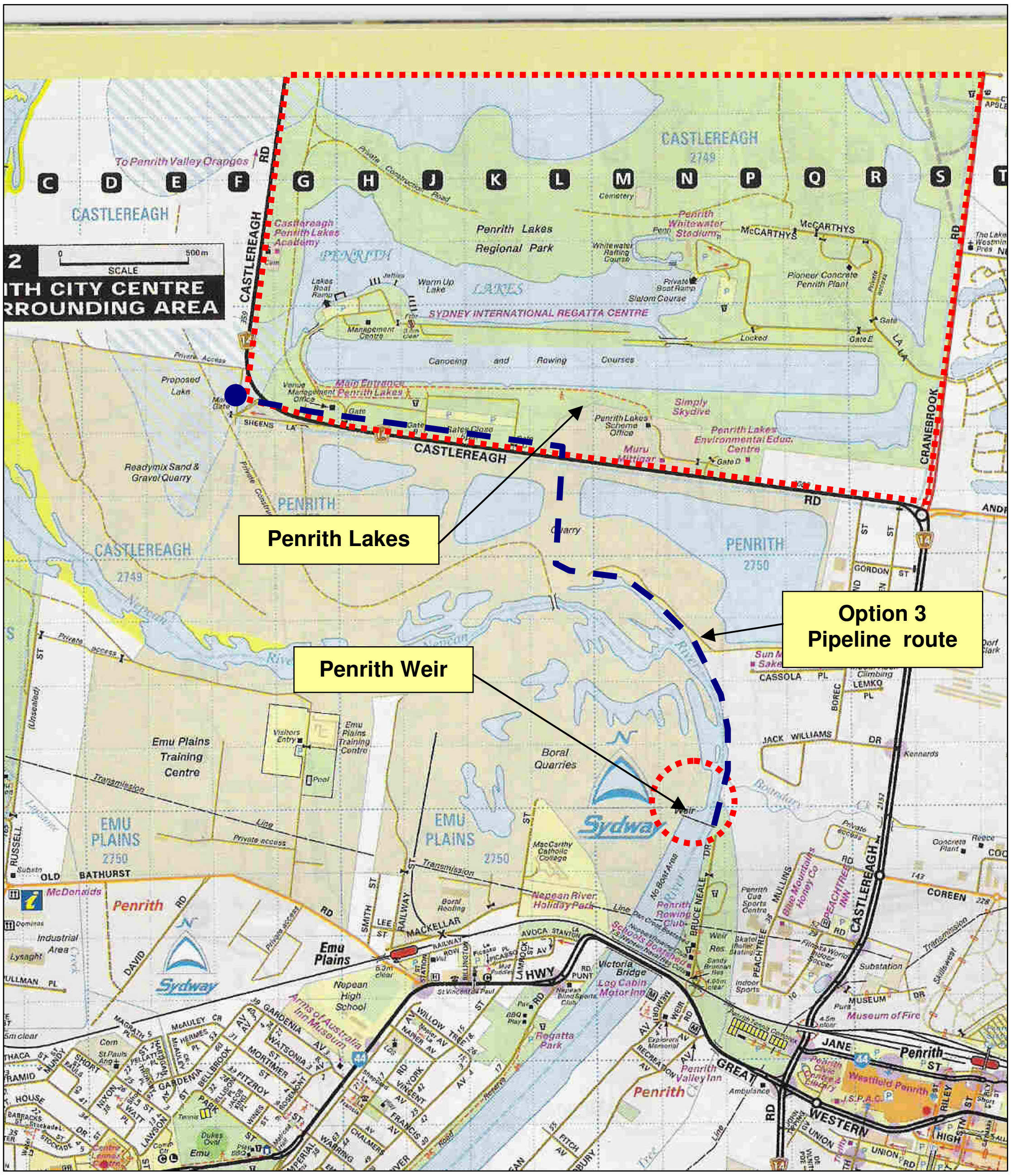

Figure 1: Locality Map

3 Aquatic Weeds

PLDC have confirmed that the transfer of weed species via a water supply pipeline from the Nepean river is a potential concern for water quality and a threat to the recreational use of the lakes.

The Nepean River has suffered extensive weed infestation in the past which is related to human impact, poor water quality, and reduced environmental flows. More recently, outbreaks of invasive weeds such as *Salvinia molesta*, *Eichhornia crassipes* and *Egeria densa* has become problematic for the Hawkesbury-Nepean River system.

The NSW Department of Primary Industries (2005) regards aquatic weeds as a serious concern in aquatic systems due to the following:

- Rapid growth and invasive nature;
- Ability to block rivers, drainage channels, dams and other aquatic environments;
- Displacing native aquatic flora and fauna;
- Reduced infiltration of sunlight into the water column;
- Changes to water temperature, pH and oxygen levels;
- Reducing gas exchange at the water surface;
- Altering the habitats of aquatic plants, fish, amphibians and waterfowl;
- Restricting the recreational use of waterways;
- Reducing the aesthetic values of waterways; and
- Reducing water quality from decomposing biomass.

The Nepean River receives water from a variety of catchments that contain urban, rural, industrial landuses and natural bushland. The Nepean River catchment has suffered poor water quality in recent years due to increasing urban pressures and stormwater run-off from rural and industrial areas.

A key component of the design for the Nepean pump is to reduce the risk of transferring aquatic weeds from the Nepean River to Penrith Lakes. Excessive growth of weeds can out compete native macrophytes and interfere with recreation activities and aesthetic qualities of the Lakes (Taylor-Wood, 2003).

The proposed inlet for the pipeline in Penrith Weir Pool is known to contain aquatic weeds including *Salvinia molesta* and *Egeria densa* and other species that may become problematic in the future, such as Lagarosiphon, Alligator Weed, Water hyacinth, Cambomba. It must be noted that weeds can also be introduced into the lakes through the spread of seed and weed fragments attached to aquatic vessels and other equipment, water fowl, and from other stormwater catchments.

In developing a method for controlling weed transfer from the Nepean River to Penrith Lakes we have considered the ecology, habit and biology of the known aquatic weed species located within the vicinity of the development, including preferred growing conditions and the reproductive strategies.

3.1.1 Salvinia (*Salvinia molesta*)

Salvinia molesta is an introduced floating fern from Brazil and is listed as a Weed of National Significance in Australia. It is declared as a noxious weed in all states of Australia (NSW Ag, 2000) and has serious environmental and economic impacts due to its invasiveness and potential for spread (DEH, 2003). It grows in still or slow moving waters where it forms a dense mat of vegetation. It has a rapid growth rate especially in warm, nutrient enriched waters, where infestations can double in size every two days (DEH, 2003).

Appearance

- Leaves are round or oval with smooth leaf margins and in pairs;
- Leaves float on the surface of the water. When not crowded, leaves are flat, but when in a dense mat leaves become folded at the centre;
- Leaves have dense waxy hairs on the surface;
- Stems are submerged and hairy, joining paired leaves; and
- Roots are long and hairy up to 25cm in length.

Salvinia is not known to produce fertile spores, but is capable of reproducing vegetatively either by breaking into daughter plants or fragmentation of the parent plant. It has been spread largely by humans through dumping, transportation of aquatic vessels and by floods or water currents (NSW Ag, 2000). Reproduction occurs when buds are produced at the stem node which develop to form daughter plants, and if a part of the stem containing a node breaks away from the main plant and grows into a new plant (DEH, 2003).

3.1.2 Brazilian Elodea (*Egeria densa*)

Egeria densa is a submerged aquatic weed native to Brazil, Uruguay and Argentina (Sainty, 1981). It has been introduced into Australia as an aquarium plant and has primarily spread through dumping of aquarium contents into waterways. It thrives in shallow, slow flowing and nutrient enriched waters (Sainty, 1981). It spreads rapidly and forms dense submerged mats especially in warm water. This weed is prolific in shallow areas of the Nepean River, but is not classified as a noxious weed in the Penrith Local Government Area. *Egeria* can form dense mats underwater that can interfere with recreational uses of a waterbody (Access Washington, 2005).

Appearance:

- Leaves are bright green in colour and are approximately 4cm long (Sainty, 1981);
- Stems are erect, cylindrical and branched;
- Flowers are emergent either floating on or rising above the water's surface;
- Flowers are white with three petals and appears in summer and late autumn (Sainty, 1981);
- Lower leaves are opposite or in whorls of 3 with upper leaves in whorls of 4 to 8 (Access Washington, 2005); and
- Grows up to 6 metres tall.


Sainty & Jacobs 2003

Egeria does not produce female flowers in Australia and reproduces vegetatively by fragmentation of the stems during autumn. Small buds form on the stems that produce new plants during spring (Sainty, 1981). The number of nodes on a shoot or stem can range from six to 12 with new plants budding from double nodes along an old shoot to produce a new plant.

3.1.3 Water Hyacinth (*Eichhornia crassipes*)

Water hyacinth is a free floating aquatic plant native of South America and was introduced into Australia as an ornamental plant (Burton, 2005). It is a major weed in temperate areas and is a noxious weed in all states of Australia. Water hyacinth thrives in still or slow moving, nutrient rich water. It is a serious weed that forms dense mats over the water surface, blocking waterways, altering aquatic ecosystems, competing with native macrophytes and contributing to poor water quality (Sainty & Jacobs, 2003).

Appearance:

- Leaves are broad and leathery. They are usually dark green in colour and are smooth, hairless and glossy (Burton, 2003);
- Leaf stalks are spongy (Burton, 2003);
- Flowers are attractive, funnel-shaped, bluish purple in colour with a yellow center and six distinct petals. Flowers are on erect stems about 60cm long (Burton, 2003);
- Roots are fibrous and featherlike and can grow up to 1 metre in length (Burton, 2003); and
- Seeds are viable and long-lived, approximately 1-1.5mm long and elliptical in

shape (Burton, 2003). Seeds can remain dormant for up to 15 years (Sainty and Jacobs, 1981).

Water hyacinth reproduces both vegetatively and via seed. Mature plants produce daughter plants on the end of horizontal vegetative stems (stolons) and can double its mass every 5 days (Burton, 2003). The spread of this weed is largely due to careless disposal of plant material from ornamental water bodies and aquariums into natural waterways, plant fragments attached to boats, spread of seed by water flow or floods and by animals.

The flower heads contain viable seed that can remain dormant in sediment up to 7 years. Flowering only lasts for one to two days during summer before beginning to wither. The flower stem then starts to bend into the water and seeds are released after two or three weeks and sinks to the bottom sediments (Burton, 2003). Growth slows during the cooler months and leaves die off. New growth occurs during spring and summer in addition to germination of seed released previously (Burton, 2003).

3.1.4 Alligator Weed (*Alternanthera philoxeriodes*)

Alligator weed is a rapid spreading noxious weed occurring both in still and flowing water in attached or free floating form. Alligator weed infestations can form dense mats extending 15 metres over the waters surface. The weed responds to high levels of nutrients and warm temperatures (Sainty, 1981). The vigorous growth of this weed is a major threat to the ecological health of natural aquatic systems. Infestations can displace native species, reduce light penetration into the water column, block flows and affect aesthetics.

Appearance

- Leaves are shiny, opposite and spear-shaped, approximately 2-7 cm long and 1-2 cm wide. Leaves are stalkless;
- Stems are creeping and can grow up to 10m long and 60cm high above the water;
- Stems are hollow when mature;
- Flowers are white and papery approximately 8-10mm in diameter on a short stalk;
- Roots are thin and stringy and are located between plant segments (nodes); and
- On land, reddish-brown tap roots can reach depths exceeding 500mm.

Alligator weed reproduces vegetatively and does not produce viable seed in Australia (CRCWM, 2003). Broken plant fragments containing at least one node can produce new plants. It is can be spread by a several means including water flow (or by flood), attachment to machinery and water crafts, animals and dumping of green waste containing fragments.

3.1.5 Lagarosiphon (*Lagarosiphon major*)

Lagarosiphon is an aquarium plant native to southern Africa that has become a serious weed in New Zealand and parts of Europe. Lagarosiphon is a submerged aquatic plant that has the potential to become a serious weed in Australia. Currently, this species is in its early stages of establishment occupying freshwater lakes, dams and slow moving streams. Its rapid growth creates dense weed mats above and below the water surface (CRCWM, 2003).


Sainty & Jacobs 2003

Appearance

- Leaves are 5-20mm long and approximately 2-3mm wide arranged in alternate spirals along the stem;
- Stems are brittle and sparsely branched 3-5mm in diameter and can grow up to 6.5m in length; and
- Flowers are very small with three petals and grow on thin, translucent filament like stalks.

In Australia, no male flowers have been recorded and it has not been known to produce seed in Australia. It largely spreads vegetatively as rhizomes that take root and produce new plants. Roots grow from the joints between the segments on the stem (nodes) and new plants are produced. Fragments can be spread via boating activities, currents, animals and careless disposal of aquarium plants (CRCWM, 2003).

3.1.6 Cambomba (*Cabomba caroliniana*)

Cambomba is native to America and is still currently sold in some Australian states as an aquarium plant. It has been identified as a Weed of National Significance due to its invasiveness, rapid spread, economic and environmental impacts (CRCWM, 2003). Large infestations produce large quantities of plant material that can reduce the water storage capacity of a waterbody, displace native aquatic flora and fauna, reduce recreational use of a waterbody and contribute to poor water quality by reducing available oxygen. It grows in nutrient rich environments. It prefers warm temperatures thriving both in clear and turbid waters.


Sainty & Jacobs 2003

Appearance

- Stems are branched with reddish brown hairs that can grow up to 2 metres in length;
- Leaves have a feathery appearance and are divided into fine branches. The leaves secrete a sticky mucous;
- Floating leaves are diamond shaped; and
- Flowers range in colours from white to pale yellow.

Cambomba spreads vegetatively and does not produce fertile seed or fruit in Australia. A detached shoot with at least one pair of leaves can grow into a new plant. Plant fragments can survive in water for up to eight weeks and pieces as small as 10mm may be viable.

4 Water Quality

Noxious aquatic weeds are often associated with nutrient-rich (eutrophic) conditions. Eutrophic water bodies promote the exponential growth of weeds by providing excessive quantities of nutrients available for biological processes and reproduction. One of the most important measures against aquatic weed problems is to prevent eutrophication (Van Zon, 1977). Therefore it is important to ensure that the water extracted from the Nepean River does not contain excessive quantities of nutrients that could contribute to potential weed infestation within the lakes.

When extracting water from the river during storm events, the first flush run-off or initial 10mm of run-off should be avoided as this contains the greatest concentration of nutrients and pollutants from the catchment. Water quality analysis undertaken by ERM Australia (2001) found that water quality was generally suitable for extraction with the exception of the period prior to the peak flow generated by a storm event.

The University of New South Wales Water Research Laboratory (2005) prepared a report investigating available environmental flows at Penrith Weir and an assessment of water quality from the river in comparison to the water quality requirements within Penrith Lakes. Their findings suggest that water from the river is expected to exceed the trigger values for the lakes approximately 50% of the time, however, the water quality from the river is better than that of other contributing catchments.

Wetlands are complex systems where biological, chemical and physical processes combine to reduce pollutant loads. Biological processes include the direct uptake of nutrients by plants, in addition to nutrient removal processes aided by micro-organisms found around the root zones of plants and soil. Some chemicals such as hydrocarbons, metals and organic compounds are broken down or converted into non-harmful forms through chemical processes such as precipitation, volatilisation and oxidation/reduction. Physical processes include slowing down the velocity of water entering the wetland, which allows sufficient time for suspended solids to settle out of the water column

It is anticipated that by extracting river water of appropriate quality and by improving water quality through the use of a constructed wetland within Penrith Lakes, the risk of weed growth will be minimised by providing conditions such as various biological, chemical and physical processes that reduce growth. Additionally, improved water quality can contribute to the recreational values of the Lakes. Pollutant reductions can be quantified during the detailed design stage through MUSIC modeling if required.

A water quality monitoring strategy can be used as a management tool to identify any management issues (for example high nutrient levels) and can be used as an indication of the health of the wetland and lakes. Monitoring can be used as a pre-emptive tool to identify conditions that could lead to weed infestations and poor water quality.

5 Constructed Wetland

In association with Maunsell and PLDC, Australian Wetlands have developed a concept design of a constructed wetland to be located adjacent to the Quarantine Lake. The wetland design was guided by the requirements for weed control, water quality and expected flows from the pump and pipeline scheme. This section describes the proposed location of the wetland, preliminary wetland sizing, layout and configuration.

5.1 Wetland Function

As part of the multiple barrier approach to weed transfer control and water quality, the incorporation of a treatment wetland into the design of the Quarantine Lake has been investigated.

The “Multiple Barrier Approach” includes:

1. Submerged pump intakes;
2. Johnson Screens on the pump intakes;
3. Rock rip rap at the inlet of the wetland;
4. Constructed Wetland with shallow and deep zones;
5. Floating silt curtain;and
6. Quarantine Lake.

The aim of the wetland would be to act as a biological filter to capture and retain any weed fragments that have escaped the Johnson Screen and as an aid in nutrient removal. The wetland will have the following functions:

- Provide an additional barrier to prevent the spread of weeds into the lakes;
- Provide competition for weed species by planting native macrophytes;
- Allow containment and removal of weed growth within wetland area; and
- Provide additional water quality treatment such as settling out of suspended solids and uptake of nutrients.

5.2 Location

The location of the treatment wetland was determined through consultation with PLDC and Maunsell Australia. PLDC desires the wetland to conform to the layout of the Quarantine Lake, in addition to, the future landuse of the area. It was determined that the best location for the wetland is to run from north to south on the eastern side of the lake (refer to Appendix 2).

5.3 Wetland Sizing

The preliminary wetland sizing was based on designing a wetland to physically filter plant vegetation and seeds. There are no design criteria or standards for this treatment purpose, hence computer modelling was not undertaken. An assessment of the hydraulic retention time (HRT) was undertaken. At the pump flow rate of $1m^3$/sec the HRT will be approximately 100 minutes. This is considered functional for the removal of plant material. This retention time is too small to expect functional nutrient removal. However, water quality modelling should also include the volume of the Quarantine Lake.

The flow velocity of the wetlands was assessed to estimate the risk of scouring. The flow velocities in the shallow wetland will be 0.33 m/s, and in the deep wetland area 0.07 m/s (a measure of flow vs. cross sectional area of the wetland). This is adequate, however care will need to be taken to establish the plants before pumping at the full rate.

5.4 Wetland Configuration

The wetland configuration was determined to maximise treatment for water quality, in addition to weed control, and will consist of alternating shallow and deep wetland cells, which are described below.

5.4.1 Shallow Wetland Cell A and C

Australian Wetlands recommend creating a shallow wetland at the inlet and outlet with an average water depth no greater than 200mm, and densely planted with native macrophytes. This depth is the optimum depth for plant growth. The objective of the wetland would be to create an environment not favourable for weed growth, provide competition for weed species by planting robust native macrophytes and aid in the removal and recycling of nutrients through a series of biochemical and physical processes.

It is intended that the plant propagules and seeds would either die or grow in these zones. Enabling them to be contained and then controlled, rather than discharging into the main lakes.

It is recommended that the wetland cell have a maximum water depth of 200mm for plant establishment and ease of monitoring. Cell A has an approximate area of $3,900m^2$ (260m x 15m) and a volume of $780m^3$. Cell C is $3,150m^2$ (210m x 15m) with a volume of $630m^3$.

Role of Plants

A number of investigations have demonstrated that water treatment is greater within densely planted systems than unplanted ones (Morris, 1999). Plants provide the following functions within a wetland system:

- Uptake nutrients such as nitrate, ammonia and phosphorus from stormwater and convert these into plant biomass;

- Decaying plant matter provides wetland sediments with organic carbon, which is an important component in the process of denitrification. Denitrification is responsible for removing nitrogen permanently from aquatic systems;

- Keeps sediments oxygenated. Plants transport oxygen to the root system that supports the establishment of beneficial micro-organisms such as nitrifying bacteria that convert ammonia to nitrates; and

- Wetland plants provide shade over the water surface, keeping the water body cool. It is widely acknowledged that warm temperatures, in addition to other factors, contribute to excessive weed growth.

The cells should be densely planted with robust species such as *Schoenoplectus validus* and *Baumea articulata* for their rapid establishment and known capacity for water treatment. Plants should be planted at a density of 4 plants per square metre. Couch turf should be installed in the upper bank beyond the waterline to enable easy access to the wetland cell for maintenance and weed monitoring.

5.4.2 Deep Wetland Cell B

Following treatment in Cell A, water would be conveyed to the deep open water wetland via pipes installed within the earth berm between the cells. Pipe sizing will be determined during the detailed design stage.

Cell B will feature open water with submerged native macrophytes such as Vallisnersia. Vallisnersia is a vigorous growing macrophyte that forms dense mats below the surface of the water. Cell B will provide additional water quality treatment by providing a physical barrier to flows, allowing suspended solids to settle out of the water column and/or attach onto biofilm that forms on the leaves. Vallisneria can also aid in the uptake and retention of nutrients. Vallisneria will also assist in stabilizing the sediments.

The open water will enable easier inspection of the wetland for any floating or attached weed species that have emerged, and removal using mechanical or manual removal. The cell will act as a containment area in the event of a serious weed infestation.

The area of Cell B has been estimated at 4500m^2 with a volume of 4500m^3 at a depth of 1m. Similarly, batter slope will have a maximum slope of 1:4 and turfed with couch.

5.4.3 Rock Rip Rap

A rock rip rap structure or similar should be installed to dissipate flows and reduce the risk of erosion in the inlet area and potential damage to the wetland. The rip rap should consist of sandstone boulders (approximately 300-500mm in diameter) keyed into a bed of coarse gravel and underlain by geotextiles. The inlet of all the wetland cells will be protected with rock rip rap, including the discharge point into the lake.

The rock rip rap zone will also assist in the filtering and control of vegetation.

5.4.4 Water Level Control

The ability to manipulate water level is an important tool in managing weeds in an aquatic environment. Constructed systems incorporating a water level control device can enable flooding or draining of the waterbody as required for weed control. Aquatic weeds can be successfully controlled by denying water to weed growth for extended periods. Allowing sediments to dry out can kill submerged and floating species, however, if sediments remain damp, there is a 50% chance of re-infestation (CRCWM, 2003).

A ‘twister’ water level control device will enable maintenance staff to drain or flood the wetland as required for various maintenance purposes. A ‘twister’ is simply a flexible elbow with a riser pipe, attached to the end of an uPVC pipe, and water level is adjusted by raising or lowering of the riser pipe attached to the elbow (refer to Appendix 2).

5.4.5 Floating Silt Curtain

A floating silt curtain is proposed to span across the small cove where the discharge point to the wetland is located. A flotation curtain produced by Geofabrics Australia or equivalent is recommended. The flotation curtain consists of geocomposite material attached to a buoyancy float that hangs vertically, aided by weights enclosed in the bottom weight sleeve. Approximately 100 lineal metres is required.

The function of the silt curtain is to provide an additional physical barrier to remaining weed fragments. There is potential for the curtain to be breached during floods.

5.4.6 Access Road

An access road has been nominated to extend around the perimeter of the wetland to allow easy access of heavy machinery for maintenance and weed monitoring. A Civil Engineer is to undertake the design of the road design during the detailed design stage.

6 Wetland Maintenance and Monitoring

6.1 Plant Establishment Phase

The plant establishment phase is the first 12-18 months period following planting. During this time, it is important to ensure that juvenile plants are protected until the plants mature and the wetland becomes established. Important maintenance activities to maintain and enhance plant growth include:

- Protecting from full pump flows;
- Watering;
- Not drowning;
- Monitoring plant growth;
- Replanting (if necessary);
- Weed control; and
- Monitoring predation monitoring (bird damage).

6.1.1 Water Level Control during Establishment

Water level control is one of the most important management tools used to ensure plant establishment and survival in a wetland system. It is a common misunderstanding that aquatic plants require deep water to grow. Wetland plants (especially juveniles) do not grow well when permanently inundated in deep water.

The following water level control measures should be noted for the establishment period:

- Maximum water depth - water levels should not submerge more than 1/3 of the average plant stem height;
- Ensure that all planted soils are kept moist and do not form a dry crust;
- Sprinkler irrigation is highly recommended. If sprinkler irrigation is not feasible, then flood irrigation should be employed as an alternative. Permanent flooding to a depth of 50-100mm is adequate; and
- Reducing water levels may be required to stimulate plant growth and for weed removal.

6.1.2 Predation Monitoring

Waterfowl are known to cause significant damage to seedlings and aquatic plants. Therefore, it is important to minimise bird damage during the establishment phase. If birds remove seedlings then replant with larger plants, or transplant clumps of well-established plants. If predation is noted, reduce the water levels to help the plants cope with the bird damage.

6.2 Basic Maintenance

Following the establishment period, plants should be well established. Established wetland plants are very durable and resilient, however they still require basic maintenance.

6.2.1 Water Level Control

Water level control is one of the most important management tools for wetland maintenance. A 'twister' water level control device is located at the outlet of each wetland cell. It may be necessary to alter water levels to:

- Stimulate new plant growth;
- Aerate the sediments;
- Replace or trim plants;
- Remove and control weeds;
- Flood irrigate; and
- Limit predation.

6.2.2 Plant Maintenance

Regular, long-term maintenance of plant species within the wetland is essential to ensure that the wetland system functions as designed. Plant health and cover should be monitored on a monthly basis beyond the plant establishment phase.

Additional plants should be installed if the following occur:

- Survival rates are below 90%;
- An obvious channel in a plant stand allows water to bypass treatment (this is also known as short circuiting); and
- Plants have been predated are unhealthy or dead.

When replanting, it is preferable to employ the following practices:

- Lower water levels in the wetlands to expose soils for planting;
- Not install plants under inundated conditions as juvenile plants do not grow well in deep water;
- Keep sediment damp as it is ideal for plant establishment;
- Do not replant in unsuitable weather conditions such as extreme heat, cold, wind or rain.

6.3 Integrated Weed Management

In the event that a weed problem occurs at the lakes, an integrated weed management strategy would be beneficial for the lakes to control and treat any weed infestation. Weed transfer control measures will not guarantee 100% protection against weed infestation. Weeds can also be introduced into the lakes by a number of ways, such as boats and equipment carrying weed fragments. This section describes monitoring and control methods for the control of aquatic weeds. The key principles of integrated weed management are:

- Monitoring for new infestations;
- Removal or control of infestations; and
- Pro-active management to prevent re-infestation.

6.4 Weed Monitoring

A weed monitoring strategy can be used to identify and treat young infestations to prevent further undesirable weed growth. It can be difficult to completely eradicate weed species once infestation occurs and the costs associated with weed removal can be significant. Therefore, the highest priority for the management of aquatic weeds is to develop and implement an effective monitoring strategy before infestations become established (CRCWM, 2003).

6.4.1 Monitoring Program

The wetland cells and quarantine lake should be vigilantly and systematically monitored for any weed infestations throughout the year. Monitoring should be undertaken by persons with the necessary skills to identify weed species. If problematic weeds appear, appropriate control measures should be implemented to prevent its spread. It is important to treat small infestations as soon as possible as excessive weed growth can become problematic and be hard to eradicate. Some weed control measures are described in the following section.

Suggested monitoring frequencies are describe below:

- Monthly monitoring of shallow and deep wetland for aquatic weeds during autumn and winter (March – August); and
- Fortnightly monitoring of shallow and deep wetland for aquatic weeds during Spring and Summer (September – February) when the risk of weed infestation is greatest.

Monitoring will involve:

- Visual inspection of the wetlands for the presence of weeds;
- Identification of weed species;
- Determination of the extent of weed infestations; and
- Management actions to contain and/or treat the infestation.

A monitoring checklist should be used for each inspection to document findings and any management actions required (refer to example in Appendix 1).

6.5 Weed Control

6.5.1 Manual Removal

Manual removal of noxious weeds can be effective in eradicating small infestations. Noxious weeds described in section 3 reproduce vegetatively which means that new plants can be produced from broken fragments of mature plants. Manual removal must be thorough to prevent this.

Free floating weeds such as Salvinia and Water Hyacinth can be removed using scoops with nets or a harvester (depending on the size of the infestation). All collected plant material should be allowed to dry out and disposed away from water at an approved landfill.

Small infestations of attached, submerged weeds such as Egeria, Lagarosiphon and Cambomba can be easily controlled and eradicated by removing the weeds by hand in shallow water. Infestations in deeper water may require suction dredging (CRCWM, 2003).

Alligator Weed (*Alternanthera philoxeriodes*)

Manual removal is effective for small young infestations that are not well established and requires digging out all root material, which can extend up to 2m deep. When removing Alligator Weed, ensure all plant fragments are removed as the plant can re-shoot from pieces.

Salvinia (*Salvinia molesta*)

Small infestations of Salvinia can be removed by hand within the shallow wetland. Ensure that all plants and fragments are removed. In deep water areas such as the deep wetland and lake, small infestations can be removed using a pool scoop or similar. Large infestations within the lake may require the use of a mechanical harvester.

Water Hyacinth (*Eichhornia crassipes*)

Draining the wetland to deny water to Water Hyacinth can be an effective control. Use floating booms and scoop nets to collect and remove the plants from open water areas.

Cambomba (*Cambomba caroliniana*)

Manual removal of plants is highly recommended. Draining the wetlands and allowing sediments to dry out can help control small infestations.

Lagarosiphon (*Lagarosiphon major*)

Mechanical control, where practicable is recommended.

6.5.2 Chemical Control

The use of herbicides to control weed infestations should only be used as a last resort when all other measures have been exhausted. Herbicides can be effective in controlling Salvinia, Water Hyacinth and Alligator Weed, however, applying herbicide in waterways can have significant effects on aquatic ecosystems. A list of approved herbicides for the control of noxious aquatic weeds can be obtained from the NSW Department of Primary Industries. Currently, no known herbicides are effective for controlling Egeria, Lagarosiphon and Cambomba.

Alligator weed (*Alternanthera philoxeriodes*)

Chemical	Application rate for Spot/Boom spraying	Recommendations
Glyphosate 360g/L Various trade names	1L in 100L of water	Actively growing from summer through winter. Floating form only.
Metsulfuron methyl Various trade names	10g in 100L of water	Apply in terrestrial situations only. A minimum of 2 years' spraying is required to achieve complete control

Salvinia (*Salvinia molesta*)

Chemical	Application rate for Spot/Boom spraying	Recommendations
Diquat		
Reglone	400mL in 100L of water 5-10L per hectare	Spray to wet all foliage thoroughly, add Agral 600. Observe withholding period.
Vegetrol	4L in 100L of water 50-100L per hectare	Apply as an overall spray, thoroughly wet foliage. Best if clean water is used. Use higher rate for dense infestation or for dirty water. Observe withholding period.
Glyphosate 360g/L Approved for use in aquatic situations. Various trade names PER 700	1L in 100L of water	Overall spray.
Orange Oil Water Clear	1L in 100L of water	Spray on to free-floating plants.

Water Hyacinth (*Eichhornia crassipes*)

Chemical	Application rate for Spot/Boom spraying	Recommendations
Diquat		
Reglone	400mL in 100L of water 5-10L per hectare	Add Agral 600 wetter; use clean water for best results. Observe withholding period.
Vegetrol	4L in 100L of water 50-100L per hectare	Apply as an overall spray, thoroughly wet foliage. Best if clean water is used. Use higher rate for dense infestation or for use in dirty water. Observe withholding period.
Glyphosate 360g/L Various trade names for aquatic use only	1-1.3L in 100L of water 6-9L per hectare	Apply when actively growing, at or beyond the early bloom stage. Use higher rate on dense infesetations
Amitrole 250g/L Various trade names	280mL to 100L of water	Apply prior to flowering

7 Conclusions and Recommendations

Weed transfer between the Nepean River and Penrith Lakes has been identified as a threat to the recreational, aesthetic and environmental values of the lakes.

Weeds of concern include:

- Salvinia (*Salvinia molesta*);
- Brazilian Elodea (*Egeria densa*);
- Water Hyacinth (*Eichhornia crassipes*);
- Alligator Weed (*Alternanthera philoxeriodes*);
- Lagarosiphon (*Lagarosiphon major*); and
- Cambomba (*Cambomba caroliniana*).

The proposed Johnson Screens should be effective at filtering out weed fragments greater than 3mm, however, there is a potential risk that smaller viable fragments are able to pass through the screens.

A multi-barrier approach to weed control is recommended to further reduce the risk of weed invasion and maintenance of water quality and consists of:

- Constructed wetland consisting of rock rip rap inlet, and alternating shallow and deep cells to act as a sacrificial waterbody for weed control;
- Physical barrier in the form of a silt curtain;
- Discharge into a Quarantine Lake; and
- An integrated weed management approach.

It is recommended that the constructed wetlands has the following characteristics:

- Rock rip rap at the inlet for flow dissipation, erosion control, and preliminary filtering of vegetative pieces;
- Shallow wetland cell at the inlet with a maximum depth of 200mm;
- Deep wetland cell with a maximum depth of 1000mm;
- Shallow wetland cell at the outlet with a maximum depth of 200mm;
- Densely planted with native macrophytes;
- Couch planted on banks to facilitate monitoring; and
- Water level control at the outlet.

Wetlands can function as an organic filter to remove weed fragments and seeds from extracted water prior to discharging into the lakes, and improve water quality by removing nutrients and other pollutants from river water. Maintaining good water quality in the lakes can reduce the risk of weed infestation. However, it should be noted that aquatic weeds could be introduced into the lakes in a number of ways, including the spread of fragments attached to aquatic vessels, such as boats and other equipments, and run-off from other contributing catchments.

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Appendix 2: Weed Monitoring Sheet

This monitoring sheet should be photocopied, completed during each inspection and filed for future reference.

Weed Monitoring Sheet					
Date:					
Inspected by:					
Wetland Cell	**Weeds Present? (Y/N)**	**If yes, identify weed species**	**% weed cover**	**Action required? (Y/N)**	**Action/Comments**
A					
B					
C					

Appendix 3: Wetland Concept Design