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Ponds for stabilising organic matter

Purpose

Waste stabilisation ponds are widely used in rural areas of Western Australia. They rely on natural micro-organisms and algae to assist in the breakdown and settlement of degradable organic matter, generally before discharge of treated effluent to land. The ponds mimic processes that occur in nature for degrading complex animal and plant wastes into simple chemicals that are suitable for reuse in the environment. The operating processes in waste stabilisation ponds are shown at Appendix A. The use of ponds fosters the destruction of disease-causing organisms and lessens the risk of fouling of natural waters. They also limit organic waste breakdown in waterways which strips oxygen out of the water, often resulting in fish and other aquatic fauna deaths.

These ponds need to be adequately designed to:

- maximise the stabilisation of wastewater and settling of solids
- avoid the generation of foul odours
- maximise the destruction of pathogenic micro-organisms
- prevent the discharge of partly treated wastes into the environment.

This note provides advice on the design, construction and operation of waste stabilisation pond systems for use in Western Australia. It is intended to assist decision-makers in setting criteria for effective retention of liquids in the ponds and design measures to ensure their effective environmental performance.

The Department of Water is responsible for managing and protecting the state's water resources. It is also a lead agency for water conservation and reuse. This note offers:

- our current views on waste stabilisation pond systems
- guidance on acceptable practices used to protect the quality of Western Australian water resources
- a basis for the development of a multi-agency code or guideline designed to balance the views of industry, government and the community, while sustaining a healthy environment.

This note provides a general guide on issues of environmental concern, and offers potential solutions based on professional judgement and precedent. The recommendations made do not override any statutory obligation or government policy statement. Alternative practical environmental solutions suited to local conditions can be considered.

Regulatory agencies should not use the note's recommendations without a site-specific assessment of any project's setting and environmental risks. Any regulatory conditions should consider the values of the surrounding environment, the safeguards in place, and take a precautionary approach. This note shall not be used as our policy position on a specific matter, unless confirmed in writing.

Scope

This note applies to constructed ponds (sometimes called lagoons) used to:

- stabilise carbon-rich wastewater containing solids of human, animal or plant origin
- assist in the reduction of disease-causing microbes
- settle out and degrade suspended solids
- contain and/or solar evaporate wastewater.

Wastewater treated in stabilisation ponds includes that derived from abattoirs, animal by-product works and feedlots, food processors, stockyards, sewage systems and wineries.

The note is not intended to apply to stormwater basins capturing rainfall runoff from buildings, paved areas or land that that is unlikely to contain significant contaminants.

Advice and recommendations

Pond location

Ponds should be constructed in stable sand, clay or loam soils on gently sloping sites with gradients of less than one in 10 where practical. Ideally inflow and transfer between ponds should be gravity-fed to minimise costs and minimise operational problems.

1 Locations that should be avoided include hard-rock, karst, seismic fault or drainage lines, peat beds, wetlands, shallow groundwater tables (within one metre to the base of the pond liner), seasonal flood-ways, disturbed soils where differential soil settlement is likely, contaminated material dumps, and designated ethnographic or heritage sites.

2 To limit occasional odour impacts from ponds, buffer zones to public places and residences should exceed 250 metres. Pond designers should consider the prevailing wind direction and, if practical, locate ponds downwind from odour-sensitive sites.

Treatment considerations and pond configurations

3 Pre-treatment of wastewater may be used upstream of ponds such as grease and bucket traps, screening, centrifuges, chemical conditioning, flotation, or sedimentation to remove coarse or incompatible solids, minimise organic loading on ponds and lessen pond maintenance needs.

4 Wastewater that contains chemicals that could inhibit oxygen transfer or harm pond microbes essential in degrading organics should not be allowed to enter pond systems. Harmful chemicals include strong acids and alkalis, disinfectants, organic solvents, poisons, pharmaceuticals, fuels and oils.

5 Normally two to four ponds in series are used to achieve adequate and consistent wastewater treatment. Typical pond configurations are provided at Appendix C. Multiple ponds offer the following advantages:

   a Provision of a sequential treatment train. High concentrations of degradable matter are initially part stabilised in an anaerobic (no free oxygen) pond. Effluent then flows to facultative ponds (with an oxygen-rich surface layer and anaerobic sludge layer near the bottom) for further stabilisation and polishing.

   b Extended waste residence time is achieved (which limits short circuiting and consequent disposal of partly treated wastewater).

   c Reduced erosion from wave action compared to a large single pond.

   d In sloping terrain, the ponds require less earthworks than single large ponds.

   e Removal of accumulated solids can be assisted by short-term pond by-pass. This allows most of the pond system to remain in operation.

6 Multiple ponds disadvantages include more pipework and earthworks in flat terrain.

7 The final pond should have a pumped discharge or water recycle facility with an emergency overflow weir.

Pond design

8 Designers should consider the following information:

   a Pond inputs

   - Wastewater volumes, including the extent of direct rainfall and any catchment run-off to ponds.
   - Wastewater quality (i.e. organic waste strength expressed as biochemical oxygen demand, suspended solids, presence of pathogens and any chemicals that may influence treatment performance).

   b Operational factors

   - Treatment mode (aerobic or anaerobic), pond depth, appropriate organic loading and retention time for treatment.
   - Seasonal pond water temperature (as warmer conditions will increase the rate of waste stabilisation).
   - Pond water balance, including inflow variability, calculated seepage via base and walls, potential rainfall impacts (single event with 20-year minimum recurrence interval and cumulative volumes), seasonal surface evaporation rates and the volume occupied by the base sludge layer.

c *Pond output*

The desired water quality to meet the end use of the treated effluent (considering other contributing environmental influences), ensuring protection of the environmental values of waterways, wetlands and aquifers (Reference 1).

9 Ponds should be constructed with a low permeability (less than 10^{-9} metres/second) natural soil liner where practical, which has been water-conditioned and compacted, see our water quality protection note 27 *Liners for containing pollutants, using engineered soils* (Reference 3).

10 Where pond liners require materials imported to the site, options include engineered soils and rigid liners (e.g. concrete or metal) or flexible synthetics (plastics) with homogeneous or composite construction, single or multi-layered. For information on synthetic liners see our water quality protection note 26 (Reference 3).

11 Synthetic liner selection should include consideration of material properties e.g. effects of ultra-violet light on exposed plastic surfaces, resistance to chemical and insect attack, liner jointing method (mechanical, heat or solvent welded), intended pond life cycle, potential for loss of liner plasticity, abrasion and perforation resistance (during installation and provision for solids removal), leak rate tolerance, and potential for sub-base soil movement.

12 Pond dimensions and location of inlet and outlet structures should minimise the risk of poor water circulation 'dead' spots and short-circuiting that results in partial treatment.

13 Bedrock or the water table presence may limit the practical base level of ponds.

14 A minimum freeboard of 400 millimetres is recommended to contain incidental rainfall and wave action. If practical, orientate longest side of pond at right angles to the prevailing wind to limit wave-caused erosion. Higher freeboards or controlled release structures may be required in extreme rainfall zones, such as in tropical areas.

15 Overland stormwater runoff should be diverted around ponds to control erosion, and extreme rainfall events managed via spillways to prevent embankment erosion.

16 Meteorological data (rainfall and evaporation) are normally based on monthly statistical information. Considerable variability may occur in practice. Pond designers should use the best local meteorological information available, and refer to online data available at < www.bom.gov.au/weather/wa > select *climate information*.

17 Where wastewater input may increase in future, design allowance should be made for expansion of pond areas.

18 Topsoil should be separately removed during construction and stockpiled for later peripheral landscaping/rehabilitation works.

19 The suitability of local soils for achieving an effective water retention structure and the geotechnical needs of perimeter walls should be considered. The use of low permeability embankment cores is recommended.

20 Pond designers should assess the risk and consequences of seismic movement causing embankment failure. Embankment design to ensure adequate stability during earthquakes (where applicable).

21 Engineering construction techniques should minimise risk of pond leakage, wall piping or slumping failures.

22 Completed earthworks should be tested to ensure even soil compaction and water retention capability has been achieved.

23 If a defined pond operational life is envisaged e.g. for temporary treatment facilities, future pond decommissioning and rehabilitation plans should be available.

24 All ponds should have security fencing to prevent inadvertent access by people and animals.

25 Appendix B summarises regulatory processes that may affect approval of stabilisation ponds.

Anaerobic ponds

Anaerobic ponds stabilise wastewater using micro-organisms that rely on combined rather than free oxygen taken from oxidised chemicals present in the pond. They generate methane and carbon dioxide gases as by-products. Stabilised solids in the waste stream settle to the floor of the pond as a sludge. These ponds are best suited to concentrated organic wastewater inputs measured as *biochemical oxygen demand (*BOD) greater than 500 milligrams/litre. For a BOD explanation, see the web page < www.rpi.edu/dept/chem-eng/Biotech-Environ/Environmental/BOD/coda.htm >. Anaerobic ponds are often used as the first pond in a treatment sequence.

26 Anaerobic ponds are generally used to reduce organic wastewater strength for subsequent treatment in facultative or aerobic ponds. Typical anaerobic pond system features are described as follows:

a A considerable water depth (generally between two and six metres).

b Design is based on volumetric loading. In the south-west of the state, loadings of 250 to 300 grams of BOD/cubic metre/day are typical. Wastewater detention times of seven to 10 days are normal and BOD reductions of 60 to 70 per cent can be expected provided recommended pond water temperatures are maintained.

c Ponds operate best with water temperatures greater than 25^{o} Celsius. The smallest practical surface area is desirable to minimise temperature fluctuations.

d A surface-floating crust of organic matter is desirable to minimise oxygen transfer from the atmosphere. The crust also acts as an odour bio-filter and assists as a temperature control blanket.

e At pond start up or if organic loading is highly variable, acid fermentation of the wastewater may generate foul odours. This may be corrected by controlled dosing with alkalis (e.g. slaked lime).

f Ponds may be covered with a fixed or floating roof, but require provision for stormwater drainage, pond gas venting, sludge removal and chemical conditioning.

g Pond wastewater inlets should be submerged to minimise odour release and surface crust disruption.

h Piped or channel outlets should be trapped e.g. using a submerged exit pipe tee-piece or baffle to prevent syphoning and transfer of surface crusts to subsequent ponds.

i Ponds periodically require sludge removal (normally after about 10 years in operation), once solids occupy more than one third of the pond depth. Sludge depth may be determined by accessing its surface with a weighted flat board on a cable or a sampling tube.

j Two ponds installed in parallel, permit one pond to operate, while the other dries out prior to removal of solids.

k Anaerobic ponds generate methane gas (natural gas). For large installations with a considerable throughput of organic matter, the pond may be covered (often with a supported membrane dome) to capture the gas for fuel to heat the pond or for power generation.

Aerobic and facultative ponds

Aerobic ponds are shallow (less than 120 centimetres deep) and rely on sunlight, atmospheric oxygen and algal cells to assist the pond microbes to stabilise wastewater.

Facultative ponds describe stratified systems that combine an aerobic surface layer of about one metre deep, with a base sludge-rich layer where anaerobic decomposition processes dominate..

27 Aerobic and facultative pond characteristics are listed as follows:

a aerobic pond water depths range from 90 to 120 centimetres

b facultative pond water depths range from 120 to 200 centimetres

c degradable organic waste input strength expressed as BOD is normally less than 500 milligrams/litre

d pond design is based on BOD loading of the pond surface (grams of BOD/square metre/day). For aerobic ponds loading of five to 25 grams of BOD/square metre/day may be used depending on climatic factors. The higher loading figures apply in warmer climates.

e A BOD loading rate of 10 grams/ square metre/ day is commonly used in the temperate region latitudes 30 to 34 degrees south. The average wastewater detention time in aerobic ponds normally exceeds 30 days.

f Where several ponds in series are used, a higher intermediate facultative pond loading rate of up to 80 grams of BOD/square metre/day may be used in areas with warm or temperate climates.

g The pond surface should be kept free of surface scums and land-based or aquatic plants (other than pond algae) to maximise air diffusion that is essential to aerobic pond microbes.

h For ponds with surface dimensions exceeding 25 metres, embankment armouring against wave action is recommended. Stone rip-rap, 'gunite', 'shotcrete' or similar may be used.

i Algal growth is a sign that ponds are operating normally; however algal blooms may seasonally decay and cause operational problems in autumn or early winter. Well operated ponds may reduce input BOD loads by up to 90 per cent, with residual BOD in effluent largely caused by breakdown of algal solids.

j Overloaded ponds may change colour, release foul odours and discharge poorly stabilised effluent. Ponds are normally a brownish-green colour due to the presence of algae. Pink ponds may indicate high levels of sulphur bacteria.

Artificially aerated ponds

28 Where available land area is restricted or landform is unsuited to naturally aerated ponds and a power supply is available, artificially aerated ponds may be used.

29 Typical aerated pond characteristics are:

a Water depths in range from two to four metres. Aerators should be designed not to scour engineered soil pond liners. Pond design is described online at < www.state.sd.us/denr/des/P&s/designcriteria/design-5.html >.

b Artificially aerated ponds rely on addition of air, using floating surface aerators or submerged bubblers to supply oxygen for respiration of aerobic microbes that stabilise the wastewater. The aerators also normally mix the contents of the pond over its full depth.

c Excess air should be evenly mixed into pond waters that contains at least twice the oxygen necessary to meet biochemical oxygen demand to effectively degrade the pond wastewater input load.

d Regular settling cycles for pond suspended solids should occur before effluent release. This may take place by turning off the aerators for a period or holding effluent in a separate settling basin. Settled solids are normally returned to the aeration basin. Pond detention time is typically less than one week.

e Skilled analysis of pond organic loading, pond micro-organism balance, aeration rates and settling characteristics are required for the successful operation of these ponds, when compared to other pond stabilisation systems.

Holding or evaporation ponds

30 These ponds are often used to contain stabilised wastewater for seasonal irrigation or solar-evaporation disposal. Pond depth is guided by site characteristics; however, large surface areas increase evaporation losses.

31 Holding or evaporation pond designers should consider variability of all water inputs and outputs.

32 A factor of safety should allow for rainfall inflow that exceeds monthly averages. The Engineers Australia publication *Australian rainfall and runoff* (Reference 5) provides systematic information for estimating stormwater volumes.

33 In areas of high annual evaporation, pond salinity should be monitored using an electrical conductivity meter to ensure effluent doesn't exceed water reuse criteria. These criteria are described in the national water quality management strategy - *Australian and New Zealand guidelines for fresh and marine water quality 2000* (Reference 1a).

34 Pond evaporation rates decrease as the salinity concentration rises in the pond into the hyper-salinity range (i.e. salt concentrations above that of seawater at 35 000 parts per million).

Polishing ponds and artificial wetlands

35 These shallow ponds containing aquatic plants e.g. reeds may be used following wastewater stabilisation to foster nutrient removal and reduce the suspended solids content of effluent. Design issues involve defining solids and nutrient loading, nominal detention times, aquatic plant type, density, and nutrient uptake, salinity build-up, risk of nuisance insect breeding, operational duration before revitalisation and treatment performance monitoring.

36 Pond water may require filtration or disinfection before discharge occurs into the environment. Effluent is commonly irrigated to promote growth of vegetation. Irrigation criteria are covered in the department's water quality protection note 22 *Irrigating vegetated land with nutrient-rich wastewater* and note 33 *Nutrient and irrigation management plans* (Reference 3).

Pond operation and maintenance

37 Water cover should be retained continuously in ponds to prevent drying out of compacted clay liners. Shrinkage cracks occur in a dry liner, which may refill with permeable material and cause excessive leakage when ponds later refill.

38 An inspection and maintenance schedule should include observation of pond condition and management of surface scums, pond stabilisation performance tests, programmed settled solids removal, dewatering and disposal. Damage to pond liners during sludge removal should be avoided. Stabilised sludge should be dewatered, then applied to land as a soil conditioner (provided it is not saline or contains harmful constituents).

39 Inlet and outlet pipework access/maintenance pits should be inspected regularly for blockages. These pits should be covered at other times.

40 Erosion control measures for outer pond banks should be installed and maintained (such as vegetation or hard capping and drainage diversion).

41 Erosion controls for inner pond banks should be installed and maintained (to limit rills and wave erosion). Rock or paving rather than vegetation on inner banks is recommended, as plants such as grasses in the water foster mosquito breeding.

42 Trees should not be established near ponds as they can limit light needed for pond micro-organisms, impede air flow and roots may damage pond embankments or liners.

43 Anaerobic ponds generally require maintenance of a bio-filter layer on the pond surface. This consists of fatty and fibrous matter floating on the surface. On larger ponds, wind action may disturb this layer and it may need artificial (bank-to-bank) partitioning barriers to retain it in place.

44 Security fencing and sign posting should be maintained regularly to deter intruders and keep out animals.

45 A contingency plan is recommended for extreme rainfall, organic overloading, poisoning of pond micro-organisms, equipment malfunctions, odour complaints or poor treatment performance.

Monitoring

46 The site operator should, at the minimum intervals indicated, monitor and record the following:

- a Appearance of pond waters (colour, extent of gas bubbling, presence of floating matter) - *weekly.*
- b If foul odours occur, check pond organic loading and organic acid concentrations - *immediately.*
- c Log maintenance actions taken in dealing with exceptional rainfall events, equipment malfunctions, and containment breaches, pipe blockages, chemical dosing or erosion problems - *weekly.*
- d Inspect pond embankments for seepage/erosion - *monthly, and after heavy rainfall*.
- e Pond input and (if practical) output volumes, organic loading (biochemical oxygen demand and suspended solids) - *six monthly.*
- f Pond performance – analysis of change in pH, electrical conductivity (salinity), biochemical oxygen demand, suspended solids and nutrients (Kjeldahl nitrogen, oxidised nitrogen and total phosphorus) measured at inlet and outlet - *six monthly.*
- g Where maintenance of groundwater quality is an issue, monitoring bores should be used to measure water tables and water quality variation during groundwater passage beneath pond - *six monthly.* Piezometers may be used to define water levels in pond embankments.
- h Sludge level in anaerobic ponds - *annually.*

47 Monitoring bores may be used to determine if contaminants are seeping from ponds situated in porous soils. See our water quality protection note 30 *Groundwater monitoring bores* for details (Reference 3).

More information

We welcome your views on this note. Feedback provided is held on our file **12940**.

To comment on this note or for more information, please contact our water source protection branch as shown below, citing the note topic and version.

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This note will be updated periodically as new information is received or industry/activity standards change. Updated versions are placed online at < www.water.wa.gov.au > select *water quality* > *publications* > *water quality protection notes.*

References and further reading

1 Australian government - Department of Environment, Water, Heritage and the Arts National water quality management strategy papers available online at < www.environment.gov.au > select *water* > *water quality*

   a *Australian and New Zealand guidelines for fresh and marine water quality 4, 2000*

   b *Australian drinking water guidelines 6, 2004*

   c *Australian guidelines for water quality monitoring and reporting 7, 2000*

2 Berger B.B. *Control of organic substances in Water and Wastewater* NDC 1987

3 Department of Water (WA) - water quality protection notes available online at < www.water.wa.gov.au > select *water quality* > *publications* > *water quality protection notes*

   - WQPN 22 *Irrigating vegetated land with nutrient rich wastewater*
   - WQPN 26 *Liners for containing pollutants, using synthetic membranes*
   - WQPN 27 *Liners for containing pollutants, using engineered soils*
   - WQPN 30 *Groundwater monitoring bores*
   - WQPN 33 *Nutrient and irrigation management plans*

4 D. Duncan Mara, Department of Civil Engineering, University of Leeds, UK *Waste stabilization ponds: effluent quality requirements and implications for process design,* IWA publishing 1996.

5 Engineers Australia publication available for purchase online at
< www.engineersmedia.com.au > search *EA books*
Australian rainfall and runoff (current edition)

6 Metropolitan Water Board Perth (WA) (now Water Corporation)
Wastewater treatment - plant operator training manuals, course 1 and 2.

7 New York State USA, Department of Environmental Conservation *Manual of instruction for wastewater treatment plant operators* 1978.

8 Public Works Department (WA)
Report on a study of oxidation pond performance and design prepared by GHD-Dwyer consultants, April 1985.

9 Schroeder ED. *Water and wastewater treatment* McGraw-Hill 1977.

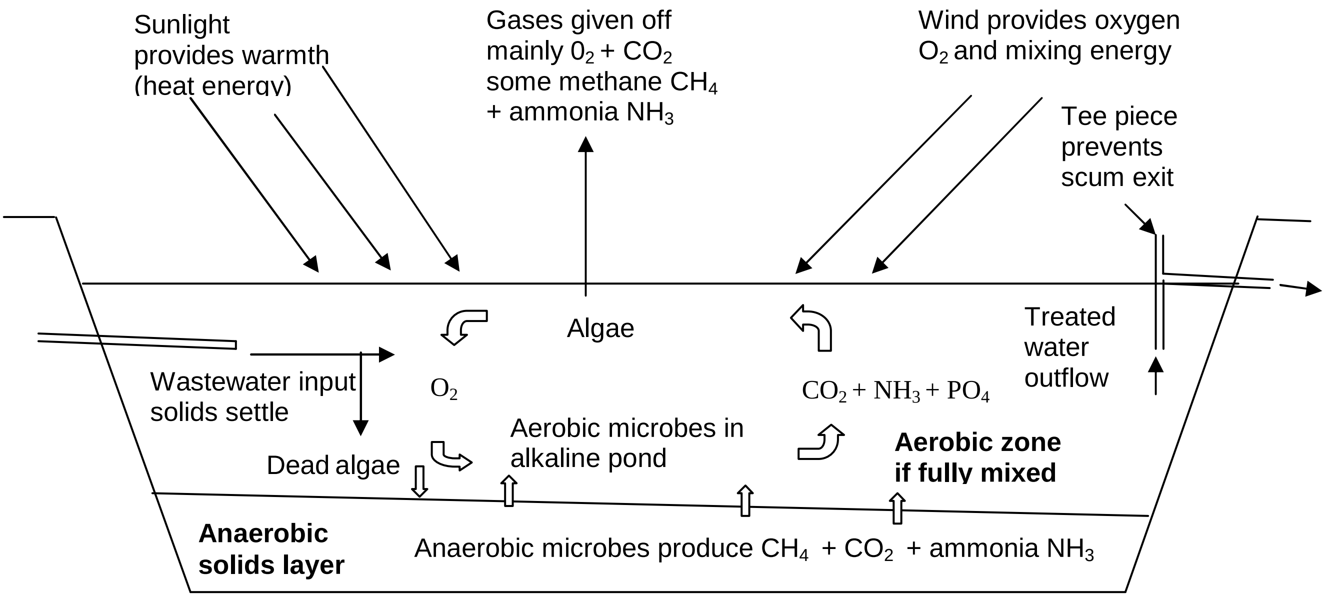
10 Standards Australia publication available for purchase at < www.saiglobal.com > select *publications*

- AS 5667 *Water quality-sampling*
- AS/NZS 1546.3 *On-site domestic wastewater management units - aerated wastewater treatment systems*
- AS/NZS 1547 *On-site domestic wastewater management*

11 University of New South Wales, School of Civil Engineering
Course on municipal water treatment presented to the Water Authority of WA, June 1992.

Appendices

Appendix A - Oxidation pond treatment process diagram



Appendix B - Statutory requirements and approvals relevant to this note include:

What's regulated	Statute	Regulatory body/ agency
Development approval	*Planning and Development Act 2005*	Local government (council) Department for Planning and Infrastructure < www.dpi.wa.gov.au >
Impact on the values and ecology of land or natural waters	*Environmental Protection Act 1986*: Part IV Environmental Impact Assessment	Minister for the Environment; with advice from the Environmental Protection Authority (WA) < www.epa.wa.gov.au >
Environmental Protection Policy	*Environmental Protection Act 1986:* Part III Environmental protection policy	Department of Environment and Conservation < www.dec.wa.gov.au >
Licensing of prescribed premises that may pollute	*Environmental Protection Act 1986:* Part V Environmental regulation	
Discharges into the Swan-Canning Estuary	*Swan and Canning Rivers Management Act 2006*	Swan River Trust < www.swanrivertrust.wa.gov.au >
Licence to take surface water and groundwater (proclaimed areas)	*Rights in Water and Irrigation Act 1914*	Department of Water - regional office < www.water.wa.gov.au >
Industrial sites in existing public drinking water source areas	*Metropolitan Water Supply, Sewerage and Drainage Act 1909*	
	Country Areas Water Supply Act 1947	
Approval to discharge into a managed waterway	*Waterways Conservation Act 1976*	
Management of human wastes Community health issues	*Health Act 1911*	Local Government Authority Department of Health < www.health.wa.gov.au >

Relevant statutes are available from the *state law publisher* at < www.slp.wa.gov.au >.

Appendix C - Typical pond configurations