The Use of Reed Beds for the Treatment of Sewage & Wastewater from Domestic Households

This document was produced as a community education document for the ratepayers of LCC and is in no means a scientific document. People wishing to find more out about reed beds are asked to look at the reference list at the back of the document or contact the Department of Local Government's Septic Safe Program.

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1.0 ON-SITE TREATMENT OF DOMESTIC WASTEWATERS

Traditionally, all wastewater generated from the household was treated on-site by a septic tank and absorption trench. Recent audits across the State on the operating performance of on-site sewage management systems have revealed that a significant number of systems are failing to meet environmental standards and community expectations. In 2001 the failure rate for failing on-site sewage management systems (e.g. septic tanks) in the Lismore City Council area was found to be %44.

The high failure rate of these on-site systems has led to more innovative solutions to the on-site treatment of wastewaters, such as, composting toilets, sand filters, and reed beds. Many of these innovative systems have split the wastewater stream into two categories:-

- Blackwater-all wastewater from the toilet or bidet.
- Greywater-essentially the rest of the wastewater stream i.e. kitchen, laundry, bathroom.

An example of a split system involves a dry composting toilet for dealing with the human excreta, reducing the water use in the house by up to 35% and producing a good friable compost. The greywater can be collected and treated using a collection tank and reed bed. Any excess urine (leachate) from the compost toilet is directed to the collection tank for treatment with subsequent disposal of the reed bed effluent to sub-surface irrigation. This document outlines the basic principles that should be adhered to by people looking to install a reed bed.

1.1 Regulatory Requirements for the Treatment and Disposal of On-Site Wastewater

Due to the high failure rate of sewage management systems, legislative reforms were introduced to the Local Government Act (1993) and companion legislation, re-establishing performance standards and management responsibilities of on-site domestic wastewaters. In response to the reforms Council was required to produce an “On-site Sewage and Wastewater Management Strategy” and introduce an audit program in order to minimise the threat failing systems may pose to public health and the environment. In July, 2003, Lismore City Council launched its “Revised On-site Sewage & Wastewater Strategy” (Appendix 2).

1.2 The Treatment Train

The term ‘treatment train’ refers to the series of processes that wastewater undertakes from its generation in the household to its disposal. There are three stages in the treatment train: collection, treatment, and disposal.

In the example shown in Figure 1, household wastewater is collected via a sanitary drainage system (i.e. pipes under the house) and discharged into a collection tank (greywater or septic tank) that acts as a primary treatment chamber for the settling of solids, flotation of oils and greases, and the anaerobic breakdown of pollutants. All collection tanks (greywater or septic) are now fitted with effluent filters (Section 5.6) to improve the quality of the effluent. Wastewater from the collection tank is either then treated to a secondary level or discharged to the land application area (disposal area).

In order to qualify as a “secondary treated” effluent, the effluent must contain no more than 20mg/L BOD and 30mg/L Total Suspended Solids. Aerated Wastewater Treatment Systems, reed beds and sand filters are examples of secondary treatment systems.

Different methods of discharging wastewater to the land application area are used, such as, absorption trenches, evapotranspiration beds, sub-surface irrigation, dripper under mulch or spray irrigation (if disinfected it can be discharged to the grounds surface).

The land application area can be planted with grass that is regularly mown in order to remove nutrients from the treatment train or Australian native plants that are suited to wet environments and local conditions can be planted between irrigation lines or along the boundary of the land application area.

Wastewater can be discharged under gravity or with the use of a pump or dosing siphon. The size of the land application area, based on the hydraulic load, may be reduced if the house has a compost toilet and water saving devices, reducing the hydraulic load by up to half.

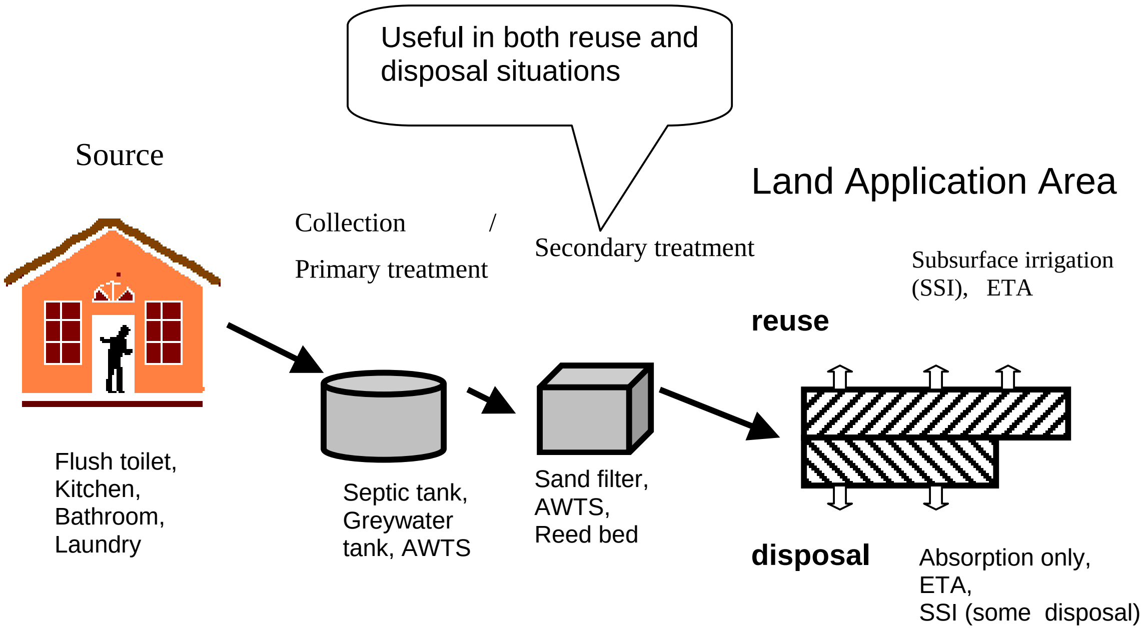


Figure 1: The Treatment Train Process

2.0 WHAT IS A REED BED?

A reed bed is essentially a channel, lined with an impermeable membrane, that is filled with gravel and planted with macrophytes i.e. reeds, rushes (Figure 2) and used to treat wastewater. Wastewater, black or grey, is passed through the root zone of the reeds where it undergoes treatment. Inlet and outlet pipes are positioned below the gravel surface, so that the water always remains below the gravel surface, thus excluding human exposure to the wastewater, mosquito breeding and unpleasant odours.

2.1 How do Reed beds work?

Primary treated effluent from the house is initially filtered prior to entering the reed bed through an effluent filter fitted to the greywater collection tank or septic tank outlet pipe. After filtration of these large solids/floatables the wastewater undergoes many processes as it passes through the reed bed.

Reed beds are generally designed to detain the wastewater for a period of 5 to 7 days. This residence time aids with the treatment by allowing sufficient time for the settling and filtering of suspended solids, nitrification/denitrification to occur, fixation onto the substrate, breakdown of organic matter and nutrient removal via micro-organisms and plant uptake. Residence time is generally governed by the surface area and depth of the reed bed.

The die-off of pathogens in a reed bed is due to predation by micro-organisms on the surface of the gravel and roots, unfavourable conditions provided by a long residence time, and the aerobic and anaerobic zones in the reed bed. Therefore, the quality of treated effluent improves with increased residence time.

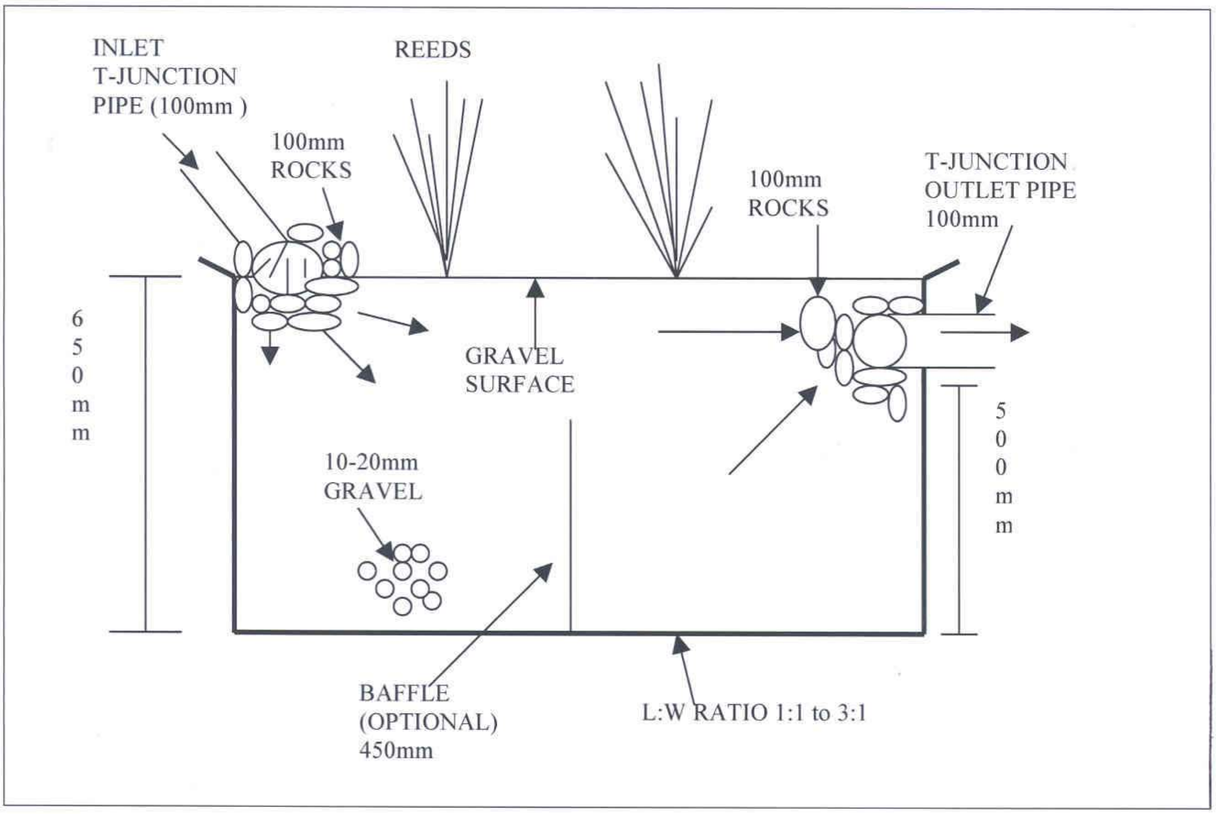


Figure 2: Basic Reed bed Design (Lateral View)

2.2 Basic Reed bed Design Parameters

Reed beds should be designed to have a wastewater residence time of 5 to 7 days and can range between 300-1000mm deep (Figure 2). Reed beds should have a length to width ratio between 3:1 and 1:1. If installing a circular reed bed it is advisable to install a central baffle and strongly consider installing inlet and outlet baffles to prevent short-circuiting of wastewater in the reed bed and a possible reduction of treatment performance.

Many reed beds contain 10-20mm gravel as a medium for the main body of the reed bed, although some reed beds do have a top layer of sand for planting the reeds in. Clogging due to solids in the influent can be minimised by installing an effluent filter (Section 5.6) on the outlet of the greywater/septic tank. Current research is indicating that once a reed bed has been established and the reeds have reached maturity that worms enter the reed bed and actually "transport" solids to the surface that would otherwise clog the reed bed.

Wastewater enters the reed bed via the inlet pipe positioned at a height greater than the outlet pipe, and disperses the wastewater as evenly as possible into the gravel. Some reed beds use perforated T-junctions (see Section 4.41) made from 100mm PVC sewer grade pipe, whilst others use perforated 300mm capped, perforated stormwater pipe (see Section 4.42). It is important to prevent surfacing of effluent and the escape of odours. Therefore, the inlet pipe should be covered with aggregate.

Large 50/100mm diameter rocks must be placed around the inlet and outlet pipes to allow the effluent to disperse easily and quickly, to minimise clogging and make checking for root intrusion easier. Some plumbers use railway ballast.

Some reed beds contain baffles that minimise short circuiting of the wastewater flow and direct the wastewater up and down through the aerobic and anaerobic zones in the reed bed, creating unfavourable conditions for pathogens and assisting nutrient removal.

The reed bed membrane can be made from ferro-concrete (concrete cattle troughs) or polyethylene (i.e. cattle troughs, water tanks cut in half, Duraplas moulds). The use of liners is discussed below in Section 4.1.

2.3 Why Install a Reed bed?

There could be many reasons to install a reed bed. It may be a personal preference or it may be related to Local Government Policy or both. The use of reed bed produces a secondary treated effluent that allows owners to better utilize (Section 6) their wastewater than had it remained primary treated. Reed bed effluent can percolate easier into the soil because it has reduced BOD and suspended solids. It also poses less of a risk to human health.

In regards to Local Government Policy, previously the Council may have given a house owner approval to install a septic tank and absorption trench within 100metres of a waterway. However, due to changes in legislation and an increasing knowledge and understanding of on-site sewage systems, it may now be a requirement that the septic tank and absorption trench, if failing, treat the wastewater to an acceptable standard prior to land disposal. If the absorption trench is failing then the installation of a reed bed will improve the quality of the septic tank effluent prior to land disposal.

The installation of a reed bed with a greater than a 5day residence time will approximately halve the nitrogen load in the wastewater and thus halve the irrigation area required for nitrogen disposal (the size of land application area's in NSW for are now based on nutrient and hydraulic loads). It will also significantly reduce faecal coliforms (i.e. pathogen indicator).

Reed beds can be used after septic or greywater tanks and are usually installed on sites on bad soils i.e. sand, pugs, clays, or steep slopes, allowing the wastewater to be treated or polished to an acceptable standard prior to land application.

2.4 When is it necessary to treat wastewater to a secondary standard?

It is usually site constraints that determine that it is necessary to treat wastewater to a secondary level. If the following site constraints are found then the use of a reed bed might be appropriate:-

- If the land application area is within 100m's of a waterway i.e. river, creek.
- If the land application area is within 40m's of a dam or dry gully.
- The soil type is medium to heavy clay (pug) or sand.
- Shallow soil depth i.e. underlying rock layer.
- High water table i.e. less than a metre below the proposed trench.
- Steep site.

2.5 How well do I need to treat my wastewater?

How well you treat the wastewater is dependent on the method of disposal e.g. Sub-surface irrigation, ETA beds, mini trenches. Sub-surface irrigation systems require the highest level of treatment out of these three options. Manufacturers of sub-surface irrigation systems, such as, Wasteflow™ and Netafim™, require that the wastewater is treated to a secondary level with BOD 20mg/L and TSS 30mg/L. A 7day residence time in the reed bed will produce a secondary treated effluent (Section 3).

If you are installing an indexing valve and mini trenches or ETA beds it is not so important to achieve a 20/30 BOD/TSS if nutrient considerations have been met because the pipes used in the beds/trenches have larger holes to allow solids to pass through. Therefore, in general, reed beds used with sub-surface irrigation systems will be slightly larger, usually in order to allow BOD levels to drop.

Essentially, the higher the treatment level required the longer the residence time.

2.6 What Macrophytes can you use?

Macrophytes i.e. sedges, reeds, play an important role in the treatment of water within a reed bed. They directly take-up nutrients, pump oxygen into the substrate and provide a food source for the micro-organisms responsible for breaking down pollutants (L.Davison & T.Headley, 2003).

Until recently*, Phragmites australis* (the Common Reed) and *Tyhpa orientalis* were the main reeds used in reed beds on the NSW North coast. However, with the understanding of reed beds growing continuously many new plant species are being used, such as, *Lomandra hystrix, Baumea articulata* and *Schoenaplectus mucronatus* (Table 1).

Davison & Headley (2003) recommend that locally occurring native species that exhibit rapid and luxurious growth should be used. These species are generally found locally on the north coast of NSW and can either be sourced from existing treatment reed beds (Appendix 3-How to dig the reeds out & rhizomes) or from some local suppliers (see suppliers list in Appendix 2).

2.7 Planting out the Reed bed

Macrophytes should be planted at a density of at least 4 to 5 clumps per square metre (approximately 30-40cm apart), with the rhizomes measuring approximately $15cm^3$. Essentially, **the denser they are planted, the better!** All shoots/stems should be trimmed to a length of 20cm before placing the clump in the gravel (Appendix 3). Reeds will grow best if the reed bed is situated in a sunny location.

Table 1. Macrophyte species suitable for use in reed beds and their maximum expected height.

Species name	Common name	Height (m)
Baumea articulata	Jointed twigrush	2.5
Baumea rubiginosa	-	1
Bolboschoenus fluviatilis	marsh clubrush	2.5
Eleocharis sphacelata	Tall spikerush	2
Lepironia articulata	-	4
Phragmites australis	Common reed	4
Schoenoplectus mucronatus	-	1
Schoenoplectus validus	River clubrush	3
Typha orientalis	Bullrush or cumbungi	4

Source: L.Davison & T.Headley, 2003.

2.8 Harvesting the Macropthyes

Harvesting (see Section 5.1 for more detail) is undertaken to remove nutrients from the reed bed and promote macrophyte growth. Harvested vegetation can be used as mulch on the reed bed or composted. If mulching the reed bed you must ensure that the amount of mulched material placed on the reed bed does not prevent the re-growth of new shoots. Council advises people to use only 20% of the harvested material on the reed bed as a mulch until such a time as you the owner knows how much mulch can be used without limiting the growth of new shoots.

Recent studies have shown that mulching the reed bed helps attract garden/compost worms that help “transport” solids in the reed bed to the gravel surface that would otherwise clog the reed bed, and thus having a positive effect on the treatment performance of the reed bed.

2.9 Altering the Height of Wastewater in a Reed bed

Some reed beds are designed with an outlet box or an internal tower that allows the water height in the reed bed to be altered. Lowering the height of the water in a reed bed can stimulate root growth and aid in treatment performance by drying out the upper layer of gravel, oxygenating the exposed area and de-clogging the reed bed. Water height should be lower in summer when micro-organism activity is at its greatest and higher in winter when micro-organism growth slows down. A drop in water height of 200mm should be sufficient. The water level should be lowered for a period of two weeks or more. Lismore City Council now requires a device to alter the water height in the reed bed.

If your reed bed does not allow for the water height to be altered, it is assumed that the water level will drop in times of hot weather especially if the house is unoccupied for a period of time i.e. holidays. Certain polyethylene cattle troughs have a bung-hole in the bottom that allows for periodical draining, if solids accumulation is considered a problem.

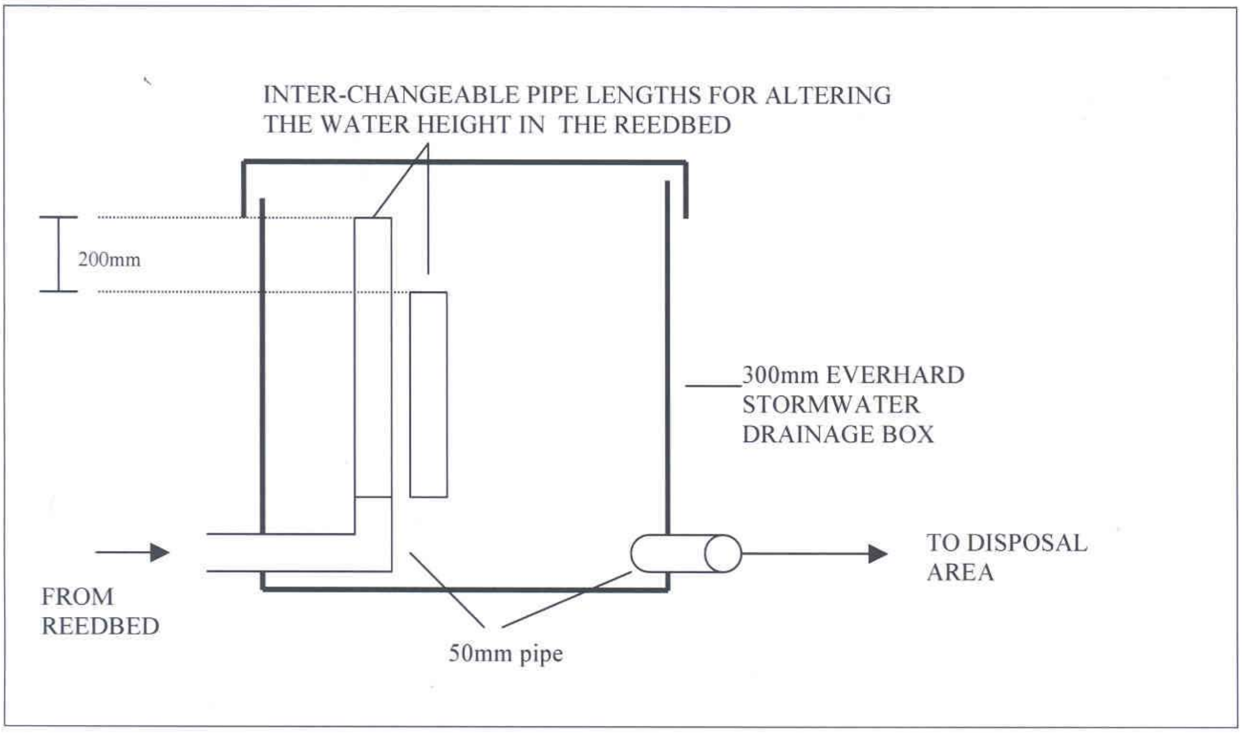


Figure 3: Water Height Distribution Box

3.0 SIZING THE REED BED

There are numerous approaches to sizing a reed bed from simple rule of thumb to computer models. Traditionally the rule of thumb method is used to size of reed beds on the north coast of NSW (sub-tropics). This is based on a reed bed surface area of $4m^2$ per person for reed beds treating blackwater or approximately 2 to $3m^2$ per person for greywater reed beds and an outlet pipe height of 500mm. This would give an approximate residence time of 7days.

Based on best scientific knowledge at the time a 7day residence time was thought to produce a secondary treated wastewater (BOD 20mg/L, TSS 30mg/L) and reduce nitrogen by 50%. However, a recent study (Headley & Davison, 2003) has shown that approximately 5days is required to reduce nitrogen by %50. Seven days would still be required to produce a secondary treated effluent unless it is a greywater reed bed where the residence time may be less than 7days.

This study has now been incorporated into Lismore City Council's on-site sewage management model (excel spreadsheet) and can provide accurate sizes for reed beds. It will not be discussed in any detail here and if in doubt on sizing your reed bed, use the rule of thumb method and provide an approximate 7day residence time.

If using the rule of thumb method and the reed bed has an outlet pipe height other than 500mm (Table 2) you will need to have different surface area's in order to have a residence time of 7 days.

Table 2: The Sizing of a Blackwater Reedbed Based on a Residence Time of 7 Days.

Outlet Pipe Height (OP) (m)	Surface Area/Person (m^2)(SAP)	Treatment Volume (L) (OPD x SAP x #people x Porosity†)	Residence Time* (Days)
0.30	6.5	3120	6.78
0.40	5	3200	6.95
0.50	4	3200	6.95
0.75	3	3600	7.83

† Based on 20mm gravel with a porosity of 0.4

* Based on a wastewater generation of 460L (115litres/person/day & a 4 person household)

3.1 Calculation of Residence Time

Residence time = Reed Bed Volume X Porosity/Daily Wastewater Generation.

Example: The size of the reed bed was based on a surface area of $4m^2$ per person to achieve a residency time of 7 days for a 5 person household. The reed bed was 10m long, by 2m wide and 0.5m deep. The residency time was found to be 8days based on a gravel porosity of 0.4, reed bed storage volume $10m^3$(10m x 2m x 0.5m) and a wastewater generation of 500L/day.

= (10 x 2 x 0.5) x 0.4/100
= 10000 x 0.4/500
= 8 days

4.0 CONSTRUCTION CONSIDERATIONS

4.1 The Use of Liners for Reed bed Construction

In 2000 LCC allowed several reed beds to be constructed using liners as a membrane on a trial basis. The most common membrane used was Canavon 7000. Unfortunately after 2years it has been decided to use alternative membranes for domestic households (e.g. Duraplas moulds, concrete) instead of using liners because of the following reasons:-

- *Phragmites australis* was found to puncture liners (Canvacon 7000) due to its aggressive growth;
- Rats were found nesting under one liner and had chewed holes in the liner;
- Poor workmanship. Many plumbers left it up to the owners to finish off the reed bed with many reed beds not having sufficient lips to prevent stormwater or soil incursion. Many people did not use rocks or sleepers to support the lip, allowing the rain to erode the lip;
- It takes longer to install a liner membrane reed bed and a lot more can go wrong in the installation process i.e. puncturing of the liner, and;
- Perceived root intrusion from nearby trees i.e. figs, mangoes.

Also the Local Government Act 1993 states that mechanical parts should last 5years and non-mechanical last 15 years. Of the liner reed bed inspected by Lismore City Council, very few were expected to last 15 years.

If a liner is used as a membrane (outside the Lismore Council Area) then one should consider the following points:-

- Do not use the common reed, Phragmites australis, as it may puncture the liner due to its aggressive growth.
- One should consider using a HDPE liner, a minimum of 0.75mm thick.
- Care should be taken to ensure the hole you dig is free from trees roots or any sharp objects.
- The liner should be placed between a protective layer of geo-textile or a similar product, such as, old carpet.
- The lip of the reed bed should be well protected from UV radiation and accidental puncturing i.e. use of railway sleepers and/or creeping vegetation.
- The lip should be a minimum of 100mm above the ground surface to prevent overland flow into the reed bed..
- Care should be taken when placing the gravel into the reed bed so sharp points do not puncture the liner.
- Care should be taken when working around the reed bed with any tools or similar objects e.g. careful if using a wiper sniper, do not push a wheel barrow full of gravel over the liner when filling the reed bed.

4.2 Suitable Membranes

The reed bed membrane can be made from:-

- Concrete cattle troughs;
- Besser blocks; and,
- Polyethylene i.e. Duraplas reed bed mould, cattle troughs, water tanks cut in half.

4.3 Site selection

A suitable site should provide good sunlight for reed growth and provide fall for the effluent leaving the primary treatment unit. Those sites on slopes may need a large length to width ratio, as the reed bed will have to follow the contour. Some house owners use their reed beds to define the border of their gardens to which the reed beds are incorporated.

4.4 Inlet and Outlet Structures

There have been many varieties of inlet and outlet structures. Traditionally the inlet and outlet structures consisted of perforated T-pipes (Section 4.41, Figure 4) or capped 300mm perforated stormwater pipe (Section 4.42, Figure 5). More recent designs have used two 150mm stormwater pipe “towers” connected together (Appendix 4) or have used arched trenching (Figure 6; Appendix 4). Essentially whatever design is used for inlet and outlets they must be easily accessed for maintenance.

4.4.1 T-Junction Inlet and Outlet Pipes

A 100mm PVC sewer pipe can be used for inlet/outlet pipes. A series of 3mm holes are drilled in the sewer pipe and a circular saw can be used to create a series of slots to allow for wastewater to discharge or enter the pipe.

It is advisable that the outlet pipe be placed as close to the bottom as possible to allow complete drainage of the reed bed if major maintenance is required. The inlet pipe should be placed as close to the gravel surface as possible but remain covered by gravel. The gravel coverage is required to prevent vermin entering the inlet pipe and then entering the house and to prevent the escape of unpleasant odours.

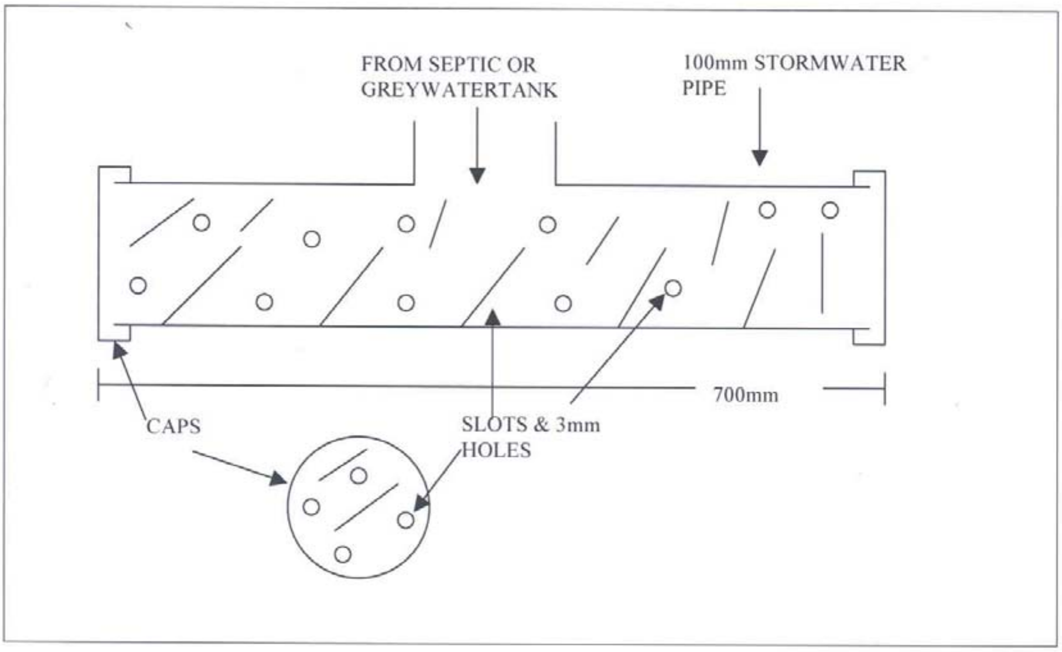


Figure 4: T-junction for inlet and Outlets

4.4.2 300mm Stormwater Inlet and Outlet Devices

Many reed beds are now using this type of inlet or outlet device or as mentioned above use a smaller size pipe of 150mm. The 300mm pipe sits in the gravel and has drilled holes greater than 5mm. The holes are located below the gravel surface. The cap can be removed to check for root intrusion.

4.4.3 Arch Trenching Inlet

The arch trenching allows for any solids to build up in the void space without reducing the reed beds ability to get the water away quickly from the inlet structure. Some people are installing these types of inlets with the selling point that when the septic tank is being pumped out the suction pipes from the truck can be placed in the inspection opening and remove any solids in the arched trenching. Council is yet to see one of these inlet pumped out and care must be taken not to damage any pipe work (Appendix 4).

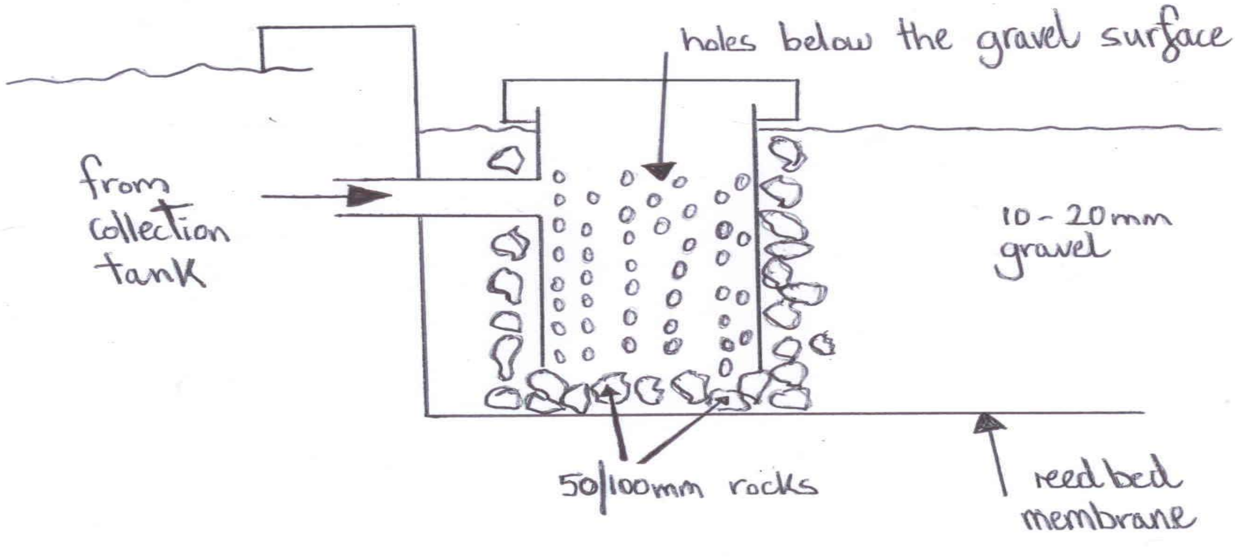


Figure 5: 300mm stormwater pipe with cap

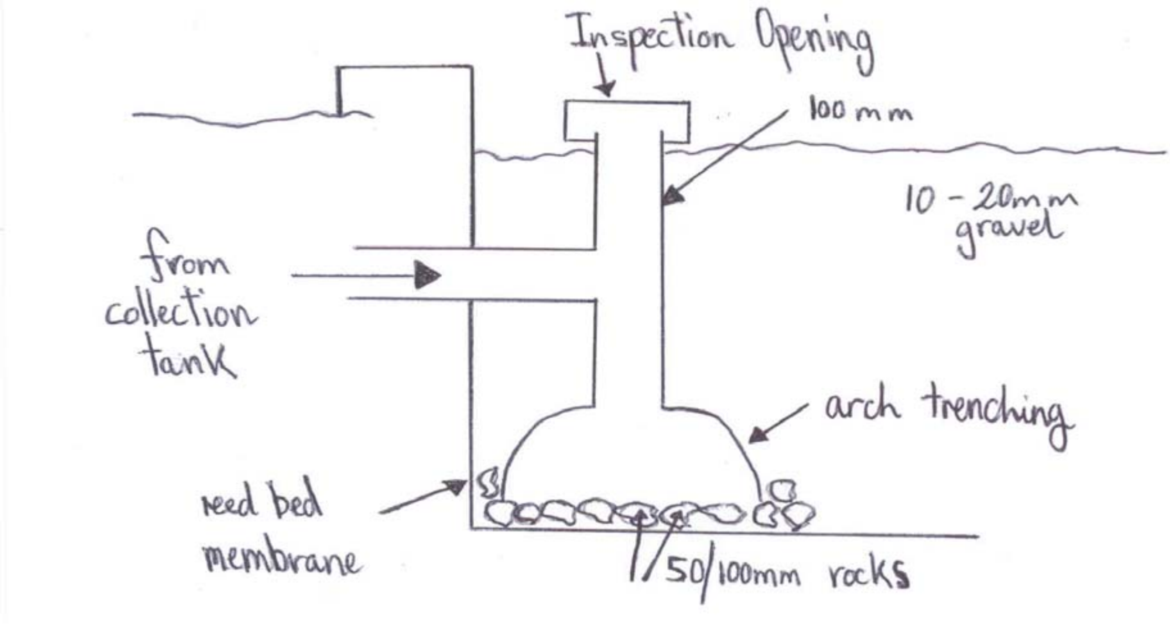


Figure 6: Diagram of Arch Trenching Inlet Design

4.5 Installing the water height outlet box or a distribution box

It is advisable when installing the outlet box or distribution box that cracker dust is first placed in the hole and compacted down so that the outlet/distribution box does not move resulting in an uneven distribution of effluent in the land application area (LAA). Some people are now installing dosing siphons or tipping buckets to provide a more even distribution of effluent in the LAA.

4.6 100mm rock at inflow & exit points

Large rocks of approximately 80-100mm diameter or rail ballast are placed at the entry and exits points of the reed bed to prevent the intrusion of reed roots, clogging, and to allow the wastewater entering the reed bed to escape quickly.

4.7 Placing gravel in the reed bed

If using a Duraplas mould for your reed bed, once your mould has been placed in the hole, you will need to ensure that when you are adding the gravel that the outside of the mould is supported/backfilled with gravel. If this is not done then the mould will bow outwards and may cause problems in the future.

4.8 Multiple reed beds. In parallel or series?

If the reed beds are placed in parallel then there is a need to ensure that the effluent discharging to the reed beds is evenly distributed. The installation of a dosing siphon or tipping bucket can alleviate this concern.

If the reed beds are placed in series there is a higher risk of the first reed bed clogging and therefore it is very important to ensure that the collection tank has an effluent filter installed and that the effluent filter is maintained regularly. Poly tank connectors may be used to join the beds together (costs approximately $16-20).

4.9 Pump Well Capacity

Pump wells are to be a minimum capacity of 1000Litres or meet the requirements of the NSW Plumbing and Drainage Code of Practice.

5.0 MAINTENANCE REQUIREMENTS

In a well designed reed bed maintenance is minimal. Please wear gloves when undertaking maintenance and avoid maintenance if you are feeling unwell or have cuts on your hands.

5.1 Harvesting

Due to the variety of macrophytes being used in reed beds there are several harvesting techniques that can be used. The harvested material can either be mulched onto the reed bed or removed. Some authors recommend harvesting in late spring and then again in early to mid-autumn prior to senescence. Senescence is a time during the winter months when the reeds stop growing and die-back to the roots. If possible, the reed bed should be de-commissioned during harvesting.

Prior to senescence, the plants translocate nutrients from the leaves and stems to the roots. It is the aim to harvest the above gravel portion before translocation of nutrients below the gravel surface. The reed rhizomes will send out new shoots after senescence, usually when the weather starts to get warmer.

5.1.1 Phragmites and Tyhpa (Bullrush)

It will not be necessary to harvest the above ground reed material in the first year but after the first year (one growing season) the reeds can be harvested twice annually. This involves cutting back reeds to a height of 20cm above the gravel surface.

5.1.2 Lomandra and Rushes

These macrophytes grow in clumps and will need to be either thinned out periodically or trimmed as above in Section 5.11.

5.2 Check blockages to pipes

Blockages should be rare if large rocks are placed around the inflow and exit pipes. When the macrophytes are growing well it may be necessary to check that their roots are not blocking the inflow and exit pipes.

5.3 Altering the Water Height

Water levels should be altered using the swivel pipe outlet device. Water levels can be low in summer and high in winter. This will dry out and declog the upper zone of the reed bed. Some reed bed operators lower their water level for 2 weeks periods in the summer months. The water level should only be lowered approximately 200mm and this should be done over the course of a few days to avoid a surge of wastewater exiting the reed bed.

5.4 Holidays

If all the occupants of the dwelling will be on holidays for an extended period (perhaps longer than 8 weeks) it will be necessary for the reed bed to receive water. A tap can either be left dripping or a friend can use the system. However, with the north coasts high rainfall conditions it is unlikely that this should be of concern to most households and it may be that rainfall provides adequate water during this time.

5.5 Two or More Reed beds

Where two or more reed beds exist, one can be decommissioned to allow maintenance to be undertaken.

5.6 Cleaning the Effluent Filter

Effluent filters are required to be fitted to the outlet of collection tanks. Before collection tank wastewater enters the reed bed it is required that it is filtered to reduce the concentration of suspended solids entering the reed bed. There are manufactured effluent filers available, such as, Biotube™ , Taylex™, and Zoeller™ filters. These filters can be easily cleaned by the system owner. This should be checked periodically and cleaned when necessary.

5.7 Mini-Trenching or Sub-surface Drip Irrigation Systems & Back-flushing the Lines

If you have a mini-trench or sub-surface drip irrigation system (pressurised emitters) such as, Wasteflow or Netafim, then you will need to flush the lines every 6 to 12months with chlorine to remove the build up of slime on the inside of the pipe work. Chlorine tablets can be dropped into the pump well before back flushing the lines.

6.0 AFTER THE REED BED: LAND APPLICATION (DISPOSAL) OPTIONS

6.1 Application Methods

The most common methods of land application are:-

1. Gravity fed to ETA beds;
2. Minimum 1000Litre pump well, pump, pumped through indexing valve to a series of mini trenches or ETA beds; and,
3. Minimum 1000Litre pump well, pump, pumped to sub-surface drip irrigation system i.e. Wasteflow™ or Netafim™.

N:B. Pump wells will require an overflow trench or surface pipe and alarms for pump failure.

6.1.1 Gravity fed to ETA beds

In most cases an owner will gravity feed to ETA beds if possible to reduce installation costs. A more effective way to apply the wastewater, whilst still using gravity, would be the use of a dosing siphon (usually 80-200Litres capacity) which will allow effluent to enter your ETA bed under pressure, thus ensuring that the wastewater will make it to the end of you ETA bed and providing a more even distribution of effluent.

6.1.2 Minimum 1000Litre pump well, pump, pumped through indexing valve to a series of small trenches

Some owners install an indexing valve that allows up to six land applications areas to be irrigated. The indexing valve pumps wastewater to the land application areas alternatively, providing an even distribution of wastewater. Once the pump has finished pumping it automatically switches to the next irrigation line and so on. Floats in the pump well attached to the pump dictate how much wastewater is delivered. These systems have been installed to water rows of trees.

6.1.3 Minimum 1000Litre pump well, pump, pumped to sub-surface drip irrigation system i.e. Wasteflow™or Netafim™

Sub-surface drip irrigation systems are usually installed under garden lawns. Treated wastewater is pumped to the irrigation lines that contain pressurized nipples that allow for a very even distribution of wastewater.

6.2 What to plant in the Land Application Area

It is important to note that the land application area is a managed area and thus what ever is planted there must be maintained. It is common practice to grass the top of evapotranspiration beds and keep the grass short to aid in evaporation. Suitable tree species can be planted around the border of the ETA beds or land application area. Melaleuca species are suitable for this. As with the grass, these plants will require pruning to remove nutrients from the system. Malaleuca's can be cut in half when approximately 2metres tall.

Shrubs should be thinned and lower branches removed to allow for air movement across the ground surface aiding in evaporation. Essentially you are trying to get a balance between evapotranspiration from the plants and evaporation from the sunlight. A vegetation list can be found in LCC's *Revised On-site Sewage & Wastewater Management Strategy, July 2003.*

Systems using an indexing valve have been planted with Malaleuca's, macadamia's or act as regeneration area's. Grass between the trees is mown regularly. Sub-surface drip irrigation systems are usually installed under garden lawns and thus are grassed. Areas to be used as regeneration areas must either be maintained or a new LAA established when the irrigation area fails.

APPENDIX 1-REFERENCES

Davison, L & Headley, T. 2003. *Macrophytes for Use in Reed Beds. Constructing a Reed Bed to Treat Run-off Water-a Guide for Nurseries*. Unpublished 2003.

Headley, T. & Davison, L. 2003. *Design Models for the Removal of BOD and Total Nitrogen in Reed Beds*. In Proceedings of On-site ’03 Conference. Future Directions for On-site Systems: Best Management Practice. Lanfax Laboratories, Armidale, NSW, Australia.

APPENDIX 2: ON-SITE SEWAGE MANAGEMENT INFORMATION SOURCES

Local Council: Lismore City Council

A copy of Lismore City Council's "Revised On-site Sewage and Wastewater Management Strategy, July 2003" and daily disposal model is available on request or from Lismore City's Council's webpage:-

www.lismore.nsw.gov.au

Environmental Health Unit, Lismore City Council (02) 6625 0565.

Department of Local Government (NSW) "Septic Safe" Campaign

On-site sewage management information can be obtained from the DLG's webpage:-

www.dlg.nsw.gov.au

Reed bed References

Kadlec, R.H. & Knight, R.L. 1996. *Treatment Wetlands.* Lewis Publishers, Boc Raton, USA.

Marshall, G. 1997. How to Construct a Reedbed for On-site Wastewater Treatment. Permaculture International Journal, Issue No.64.

Reed, S.C., Crites, R.W. & Middlebrooks, E.J. 1995. *Natural Systems for Waste Management and Treatment. 2nd Edition.* McGraw-Hill Inc., New York, USA.

Sourcing Macrophytes

Eco-living Consultants, Bexhill. Contact: Tom Headley,.
Phone (02)6628 4243, Email: ecoliving@optusnet.com.au

Impact Grasses, Loganholme, Sth QLD. Contact: John Goedemans
Phone (07)3209 9001. Email: johng@impactgrasses

Sourcing Reed Bed Membranes

Duraplas, Alstonville. Phone: 1800 655 938. Reed bed moulds 3.1mx2mx.64m, cost $400 approx.
Rural Buying Service, Lismore. Polyethylene cattle troughs available.
Grahams Concreting, Kyogle. Phone (02)66 321978. Concrete cattle troughs available.
Tweed tanks, Murwillumbah. Polyethylene cattle troughs available.

APPENDIX 3: REED COLLECTION FROM AN EXISTING REEDBED AND PLANTING PREPARATION

COLLECTION

When removing reeds from an existing reedbed one should attempt to thin out the existing stand of reeds in order to encourage the remaining reeds to grow and cause the least disturbance. Gloves should be worn when removing the reeds. Gravel can be moved from around the base of the reed's stem and a shovel used to remove the rhizome. You are advised if it is possible to lower the water level in the reed bed prior to removing the reeds. This will reduce the human contact with the wastewater and allow any disturbance of solids to settle before wastewater is discharged from the reed bed.

The rhizome's of the collected reed's should measure approximately $15cm^3$. After removing the rhizomes from the reedbed the gravel should be replaced and additional gravel used when necessary.

PREPARATION

The stems of the collected reeds should be cut to a length of approximately 20cm. The rhizomes can be cleaned with a hose to remove dirt and make them easier to replant. Cleaning will also reduce the possibility of introducing any pathogens with the rhizomes. The collected reeds can be kept in a damp cloth until replanting.

PLANTING

The rhizome's should be planted at a density of at least 5 rhizomes per square metre. **THE DENSER THE BETTER.** The rhizomes are planted at a depth of approximately 100 to 150mm below the gravel surface. The trimmed stems will soon begin to grow and the cut stems help draw oxygen down into the root system. Water should be maintained in the reedbed to prevent rhizomes drying out and dying.

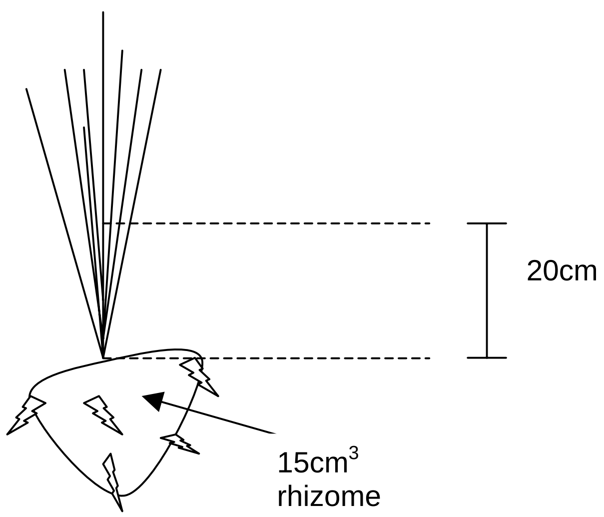


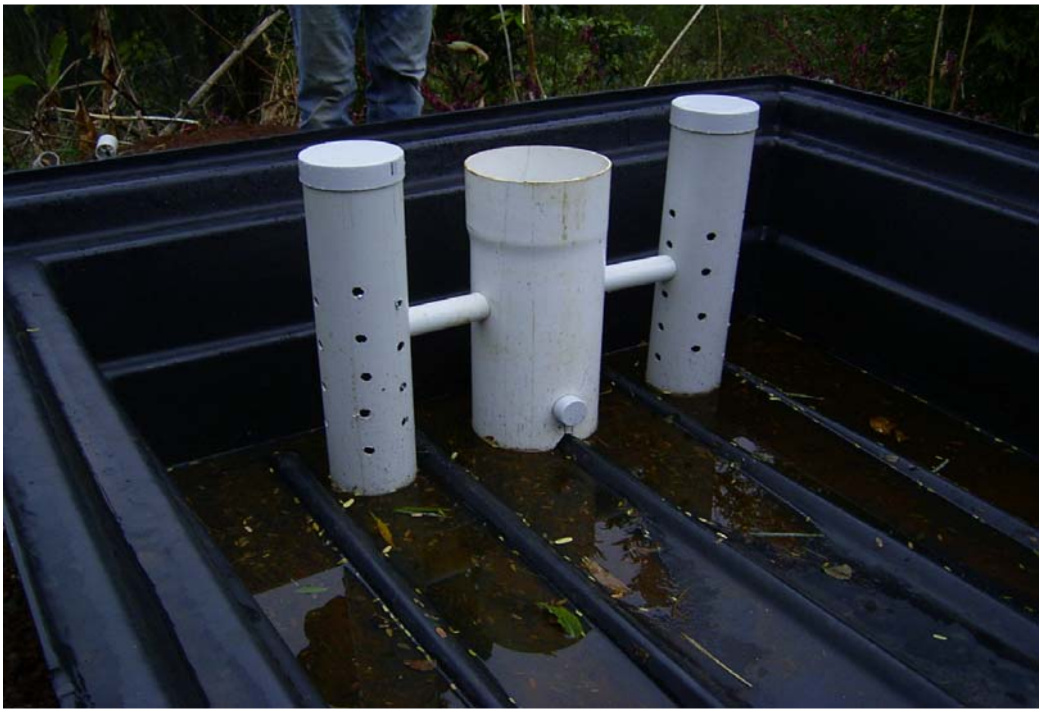
Figure 6: Collected Reed and Rhizome

Polyethylene Cattle Trough Reed Bed planted with *Lomandra hystrix*

Small Greywater Reed Bed prior to planting with *Phragmites australis*

Duraplas Reed Bed Mould with an Arch Trenching Inlet. Moulds cost $390 And are the most popular membrane used for reed bed construction. Measures 3.1m long, 2m wide and 640mm deep.

Polyethylene cattle trough planted with *Lomandra hystrix*. Note the baffle after the inlet structure and before the outlet structure.



Outlet towers in a Duraplas mould

Water height adjuster inside a 300mm outlet tower