REUSE OF SEPTIC TANK EFFLUENT USING A SYSTEM CAPABLE OF A C.E.D. SCHEME

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Abstract

The safe reuse of household wastewater for garden watering is highly desirable, particularly as the potable water supply in Australia is limited and 40-50% is used on household gardens. Soil importation overcomes many of the problems which occur in on-site wastewater disposal areas from soils with poor drainage capacity. Effluent reuse through evapotranspiration rather than on-site soil absorption eliminates most of the concerns about contamination of groundwater and waterways. A low maintenance septic tank design has been developed to achieve the safe reuse of effluent using evapotranspiration. This system is based on maintaining aerobic soil conditions in mounded garden beds to maximise natural processes in the treatment and reuse of effluent. Intermittent dosing with effluent every sixth day on parts of the garden bed mounds is achieved with an automatic valve system. Intermittent irrigation is incorporated into this system to provide a long delay between soil saturations so that a large number of plants, including native species, can be used in the garden bed vegetation.

Initial experimentation has been carried out on the irrigation concept with different plant species to assess the effectiveness of the system. The results of this experimentation, the septic tank design and the intermittent irrigation system are detailed.

This concept also has a significant advantage over other on-site systems in that it provides the core facilities for a future common effluent drainage scheme, if required. This system provides for major cost savings (approx. 80%) in the collection, treatment and decentralised sewage treatment for groups of 30-200 households for all or part of each household's on-site septic tank effluent. This design enables both on-site garden bed irrigation and off-site sewage treatment to be achieved at the same time. Details of these cost savings are explained.

Keywords

aerobic soil treatment, common effluent drainage, decentralised, evapotranspiration, garden bed mounds, sewage treatment, intermittent irrigation, septic tank, wastewater reuse,

1 Background

Most acreage allotments have on-site wastewater treatment systems, mainly septic tanks, with trenches for soil absorption of the effluent. Many septic tank systems fail due to the hydraulic overloading of their soil absorption areas with surface contamination, health risks and stormwater runoff into waterways. Hydraulic overloading occurs from a number of factors.

- Clogging of the soil from the carryover of solids out of the septic tank;
- Inadequate design of the soil absorption system;
- Non uniform flows causing localised hydraulic overloading leading to anaerobic ponding conditions and progressive trench failure; and
- Sodium salt buildup reducing the hydraulic capacity of the soil absorption area.

The failure of septic tank systems is being addressed in different ways by State and Local Governments. Many of the policies and proposals which deal with on-site wastewater treatment have conflicting objectives, such as reuse of the wastewater and minimising health risks. There are major differences between government authorities and within the local communities on what is an acceptable health risk and on what is an acceptable environmental impact from on-site wastewater treatment systems. There has been a large increase in on-site aerated wastewater treatment systems (AWTS) as a response to the problems with conventional septic tanks. Some authorities advocate the abolition of on-site systems altogether and require sewerage reticulation with centralised treatment facilities. However, due to the high capital cost, transportation costs and the environmental impacts of large effluent flows from centralised on-site sewage treatment facilities, on-site wastewater treatment systems will continue to be necessary in the future.

In the Beaudesert Shire, septic tanks are only approved in a spilt system because of the failure of all purpose septic tanks and septic trenches in the past. In the split system, the greywater is surface irrigated and the blackwater is disposed of in septic trenches. The type of residential development occurring in Beaudesert Shire is small acreage allotments where the cost of sewerage reticulation is prohibitive. In the most recent developments, there has been a requirement for aerated wastewater treatment plants to be installed. These are small self contained proprietary systems consisting of a combination of pumps, airblowers and contact media for bacterial growth which provides aerobic treatment to the effluent after it has passed through an anerobic compartment similar to a septic tank. This further treatment, including disinfection, achieves a final effluent which is suitable for surface irrigation. Surface irrigation is carried out on designated garden bed areas which are sized according to AS1547 (Standards Australia, 1994)based on soil percolation tests. Surface irrigation, with its high evaporation rate, avoids many of the hydraulic overloading problems which can occur with subsurface irrigation systems.

Reforms are being proposed in sewerage legislation which will affect the present approval of on-site wastewater systems in the Beaudesert Shire. These reform proposals will make surface irrigation of aerated wastewater treatment effluent more difficult to approve and will also preclude the surface irrigation of greywater. There is already a high degree of community dissatisfaction with aerated wastewater treatment systems due to their high operation and maintenance costs. These costs are approximately $600 per annum and come from the quarterly maintenance service costs, Council monitoring and inspection fees, power for the pumps and airblowers, replacement every 2-4 years of the pumps and airblowers due to mechanical failure, chemicals for disinfection and periodic solids removal. These high annual costs and the high initial cost of the aerated wastewater treatment and garden bed irrigation area cause community dissatisfaction, especially where poor performance occurs, but mainly from the fact that effluent is not available for general garden watering.

In the areas where split system septic tanks are being installed, there is a high level of acceptance and satisfaction with the surface irrigation of greywater despite the malodours and potential health risks from these systems. The prohibition of surface irrigation with greywater will have a major impact on costs. The costs of an all purpose septic tank will be higher together with the much greater cost for large areas of septic absorption trenches to cope with the greywater hydraulic flows. In the past it has been found that even with large areas of septic absorption trenches hydraulic failures have occurred.

There is an urgent need, therefore, to come up with a low cost on-site system which has low maintenance costs compared to the aerated wastewater treatment systems and provides an alternative to a convential septic tank system. (Department of Local Government, New South Wales, 1998)

2 Septic Tank Design

The septic tank design used in this concept is one that has been developed by Taylex Pty Ltd, a local manufacturer on Queensland's Gold Coast. A plan of this system is detailed as Appendix 1. The volume of the tank is 10 000 litres while the solids capacity is 6 100 litres. This large capacity gives 6-8 days sedimentation which improves effluent quality, provides a large buffer for toxic discharges and enables a long period (10-15 years) before any pump-out of accumulated solids is required. The tank is large enough to allow for an integrated effluent pump well with a volume of 1 000 litres. This enables the daily wastewater output, even from large households, to be pumped out in one continuous pump cycle.

Pumping of the effluent is required for the following reasons, even though it is energy intensive compared to gravity flow.

- Pumping of the effluent enables a uniform flow to be obtained and this is critical to obtaining an even distribution of effluent in the soil treatment and garden mounds.

- Pumping of the effluent provides the hydraulic power for an automatic rotating valve which is an essential requirement for intermittent irrigation.

- Pumping of the effluent also provides flexibility in design so that the system is suitable for all sites, regardless of topography.

This flexibility is important where, for unforeseen reasons, a new garden bed area or an increase in design area is required. With a pumped effluent system, changes in irrigation layout can be made with little cost. This flexibility is not available with septic absorption trenches relying on gravity flows. When septic trenches fail, the cost of rectification is so high or impractical, that mostly nothing is able to be done about the problems. It is here that septic tanks have incurred their poor reputation. (Cogger, 1997)

Three stages of sedimentation are proposed to maximise solids and oil/grease retention within the septic tank. A Zabel static filter is provided in the central chamber just prior to the effluent discharge point into the integrated pump well. The Zabel filter is to ensure that solids are retained within the septic tank and are not carried over into the soil treatment and reuse areas. The central chamber containing the Zabel filter has been designed with an access lid to enable convenient maintenance of the Zable filter through an annual hose-off of any accumulated solids. The Zabel filter also improves effluent quality by filtering the effluent through the biological slime which builds up on its filtration plates.

The pump system consists of a single submersible pump with a capacity of 1.7 L/sec at 7 m head. The pump discharge piping has been designed with fittings to simplify pump removal for any repairs, maintenance or replacement. The pump float switch system can be simply adjusted to reduce pump-out volumes for shorter times between garden bed saturations, if necessary. There is also a high level alarm system which activates an aboveground flashing strobe light system. This light system is based on 12 volts for safety reasons. There is a buffer of 48 hours before septic overflows occur should the pump fail or need repairs.

3 Intermittent Irrigation System

The discharge pipe diameter is 32 mm and this diameter piping is taken through in low pressure polythene to a six slot automatic rotating valve. The valve has six outlets for 25 mm dia. black polythene pipe and should be located centrally to limit the length of pumping to around 70 metres from the valve. The rotating valve has to be set aboveground to prevent backflow of effluent when pumping ceases. The hydraulic pressure of the pumped effluent causes the valve to rotate to a different outlet on each pump-out cycle. This means that up to six different parts of the garden beds can be saturated with effluent in a fixed rotation cycle. Where the pump-out volume is fixed to average daily wastewater flows, say 800 litres, then the cycle would be six days between saturations for each part of the garden beds.

The irrigation design requires six separate lines to be installed to different parts of the mounded garden beds. The total area of garden bed is 210 m^2, that is, each irrigation line has to be designed to provide a uniform distribution within 35 m^2 of garden bed area. The layout of the garden beds should be in at least two separate areas with a maximum width of five metres. The design of the irrigation system is critical for even distribution of the effluent. The optimum design is for the last twenty metres of the 25 mm dia. pressure pipe to be drilled horizontally through both sides of the pipe with a 5 mm dia. drill. Ten holes are commenced at one metre from the end of the pipe and then at two metre centre to centre intervals.

A ring main system gives the optimum distribution. The tee joint should be located so that there is a one metre separation to each outlet point from both sides of the tee joint giving ten equal spacings of two metres between distribution holes in a ring main layout. Prior to the tee joint being connected, a slotted agricultural drainage pipe 65 mm dia. is threaded over the irrigation outlet piping, so when the tee joint is connected the two pipes form into a single twenty metre circumference layout where the pumped effluent is distributed uniformly within the slotted agricultural drainage pipe. The agricultural drainage pipe:

- Facilitates even distribution along its length;
- Prevents pump flow blowouts through the soil to the surface;
- Minimises root intrusion through having an air gap between the drainage pipe and the pressure pipe;
- Facilitates future maintenance of the pressure piping, if required; and
- Places the effluent more centrally in the mounded soil to maximise the evaporation rate of the effluent.

4 Garden Bed Design

The garden bed design concept is to provide landscaping for the allotment and, in addition, have a controlled soil for the breakdown of pathogens and nutrients. The size of the garden bed and the frequency of saturation is a balance between several factors into which research is currently being carried out. These factors include the amount of household wastewater discharge, nutrient and sodium salt levels, rainfall, plant transpiration rates and the evaporation rate for the locality. A balance has to be achieved between providing sufficient water for plants in growth periods and having an excess of water when plant growth is low. This balance can be readily achieved by adjusting the pump-out volume if problems occur. For a large family with a high wastewater discharge the larger pump-out volume of 1 000 litres may be preferable. With a two person household and lower wastewater production, a lower pump-out volume and more frequent soil saturations may be needed to provide sufficient water for the plant vegetation in peak water demand periods. The objective is to maintain aerobic soil conditions and allow a long period between saturations so that most plant species, including natives, can be grown in the garden beds. Native plant species are desirable to provide habitat and food sources for wildlife. Experimentation is being carried out on the effect of effluent watering on the native plants endemic to the Beaudesert Shire area so that their use in the garden beds can benefit the natural environment.

The garden beds are proposed with 200 mm of imported sandy loam fill. (Jepperson, 1996) The use of sandy loam provides benefits. The clay component within this type of soil provides a filter and absorption medium for phosphorus and pathogens. The fine sand material in this soil enables an even distribution of effluent and maximises evaporation rates. The soil pore space also allows sufficient volume for coping with up to one kilolitre of effluent without exceeding its field discharge capacity. The use of a sandy loam soil facilitates plant growth and helps ensure that the effluent is treated adequately in the soil system. Nitrogen is removed by adsorption, fixation, volatilisation, biological uptake and denitrification. The organic matter within septic tank effluent provides the carbon source to feed the denitrifying bacteria. Denitrification potential is greater in finer drained soils, since the smaller pores have pockets of anoxia. The removal of phosphorus in the garden bed soil occurs from plant uptake, biological immobilisation, and adsorption and precipitation processes. Again, phosphorus sorption is enhanced with clay and the organic matter in shallow disposal systems. Similarly, pathogen removal is increased as antagonistic microflora are likely to be more abundant in the near-surface soil. (Venhuizen, 1997)

The use of imported soil in the proposed garden beds enables this system to have minimal reliance on the allotment soil characteristics. In Beaudesert, there are heavy clay soils in some areas where soil percolation tests indicate an effluent disposal of 800-1000 m^2 in area. In practice, there is almost no feasible way of achieving uniform effluent distribution over such a large area. In addition, these large garden bed areas are not attractive to, nor readily maintained by, householders. In contrast, the careful design of these garden beds ensures that rapid plant growth will be achieved, thereby providing visual landscape benefits for householders using this system. Once the vegetation is established little maintenance should be necessary due to the integration of plant species to provide both ground cover and a tree canopy.

5 Potential Common Effluent Drainage Scheme

This septic tank design provides the core facilities for a common effluent drainage scheme. There is a large capacity septic tank for solids retention, an in-tank filter to ensure there are no solids or screenings for pumping, a pump well and submersible pump and a distribution valve to enable part or all of the effluent to be pumped off-site to a localised sewage treatment plant. The option of being able to pump only part of the effluent off-site has major cost savings in the treatment plant capital and operational costs, and in the environmental impact of the off-site reuse or disposal of the effluent. The assimilative capacity of the on-site garden beds for effluent irrigation can be used to obtain major cost savings. This will also maintain the on-site landscaping and help reduce potable water resource consumption through reduced garden watering.

There is a long term limitation within on-site allotment soils, that are used for household wastewater treatment and effluent disposal, to cope with the wastewater chemicals being constantly irrigated onto and into them. For example, the sodium salts used as fillers in washing powder detergents (Patterson, 1997) can buildup in the irrigated soil, severely reducing the hydraulic capacity of the soil. Even in garden beds designed for plant uptake of nutrients in the effluent, any excess nutrients will buildup and start to leach out in rain events over time. The flexibility of having an on-site system which can readily form part of a cost effective off-site wastewater treatment system is a major benefit when a strategic overview of on-site wastewater treatment is taken.

The costs of providing off-site sewage treatment are significantly reduced where the on-site treatment facility can be used with minimal cost. With this design, all that would be required for effluent collection, is a length of pressure line to the front boundary with a non return valve and an adjustment to the irrigation areas within the garden beds. The collection of the effluent through a pressure main system, on-site and off-site, enables the following cost savings:

- A small diameter main is adequate due to the effluent flow being pressurised and free from solids or screenings;

- Construction costs are low because the main can be laid at a minimum depth (600 mm) irrespective of topography;

- Excavation using a ditch witch is possible with major savings in the pressure main bedding and restoration costs;

- Connection and maintenance are lower due to the shallow main depth facilitating ease of access; and

- Stormwater infiltration is eliminated by using a pressure main for effluent transportation.

There are further savings in this concept through having an existing population to contribute to the cost of the off-site sewage treatment plant scheme. The holding costs normally involved in providing a sewerage scheme ahead of population growth are avoided. The fact that only part of the effluent needs to be collected and treated results in large capital and recurrent cost savings through having a smaller diameter collection main, smaller pumps, less power usage, smaller capacity treatment plant and less impact on the environment from the effluent. The effective use of the sustainable assimilative capacity of the allotment soil enables major cost savings in providing off-site sewerage treatment. The amount of the savings in this concept, over the cost of a gravity reticulation, pump stations and centralised treatment scheme, is at least 80%. The savings from having garden bed watering with household wastewater rather than from the potable supply have not been calculated.

In small schemes it would also be possible to collect all the on-site septic effluent, treat it to a very high standard and return the effluent for continued reuse using the irrigation system and garden beds already constructed. Another possibility is for full on-site effluent reuse during plant growth periods and operation of the common effluent drainage (CED) scheme only during low growth periods again with major cost savings.

6 Experimentation and Results

Two sites have been approved with this new on-site wastewater treatment system. The householders have signed agreements to allow testing to be carried out.

7 Research Method

A meter has been installed on the pump line to the rotator valve so that effluent discharge flows can be measured. A rain gauge at each site provides the amount of additional water which has to be included in the evaporation and soil absorption calculations. The nutrient levels in the wastewater effluent are being tested monthly as well as in the soil to assess phosphorus accumulation. The BOD_5 and TSS are also being measured with the monthly effluent nutrient analysis. The moisture content in the natural soil under the mounded garden beds is also being monitored monthly.

The solids accumulation in the septic tank will be measured at the end of the six month testing period so that the period before a pump-out of the solids is needed can be extrapolated. The garden beds have been landscaped in accordance with a schedule detailed as Appendix 2.

Species with a low tolerance to high nutrient and a high soil moisture content have been selected for parts of each garden bed to assess the effectiveness of this irrigation system. The testing program is being carried out through the critical low plant growth period where moisture and nutrient buildup in the garden beds will be higher than at any other time. In future, plant growth will be higher due to the garden bed having been established for twelve months. If the native species survive this initial moist soil and high nutrient regime, then it is likely that there will be no restrictions on the plant species which can be used in this type of irrigation.

In one part of the garden beds, the existing soil will be covered with plastic so that there is no reliance on the soil underlying the mound at all. This barrier will provide evidence of the efficiency, or otherwise, of the mounded garden bed concept with intermittent saturation. Should the field capacity of the mounded soil be exceeded then the plastic will be punctured to use the underlying soil absorption capacity. The trial over the next six months (May-October) is occurring when the plant growth is establishing and also has low growth so the practical efficiency of this system will be assessed in the most onerous regime possible.

In another part of the garden bed, the agricultural drainage pipe will be deleted and the pressure pipe covered with aggregate for even dispersion, and to prevent the pressurised flow jetting to the garden surface. The purpose being to assess the uniformity of this distribution system as a forerunner to underlying the pressure pipe with aluminium oxide clay for phosphorus removal. Phosphorus accumulation may not be a concern due to the recent reduction in the phosphorus content of most detergents and washing powders. However, should phosphorus accumulation become a constraint, then the use of aluminium oxide clay, underlying the pressure pipe, should provide a medium to long term solution.

The last experiment is about the use of mulch on the garden bed surface. One garden bed will be covered with a pine bark mulch with the remaining beds uncovered. Mulch is used to prevent weed growth in the period before ground cover species and shrub canopy growth is sufficient to prevent weed intrusion. The mulch covering reduces maintenance and the garden bed is more visually appealing. However, mulch reduces the evaporation rate of the soil and the evaporation rate needs to be maximised to reduce mounded garden bed costs. The difference between a mulched and unmulched garden bed surface will be assessed.

8 CONCLUSION

This septic tank design and intermittent irrigation system in this concept has many advantages over the conventional septic tank and septic absorption trench system. In summary, it provides

- Reuse of effluent rather than disposal;
- Low capital costs and lower maintenance costs compared to aerated wastewater treatment systems;
- Flexibility to cope with sloping sites and areas with poor drainage capacity;
- Enhancement of the natural environment for householders;
- Nutrient uptake and disposal of effluent without groundwater contamination;
- Controlled soil, large capacity treatment and the simple processes enable a relatively problem free on-site wastewater treatment system; and
- Potential for both cost effective decentralised sewerage treatment for 30-200 households whilst retaining on-site wastewater reuse.

The concept uses proven on-site wastewater treatment technology with an irrigation concept which creates a natural environment to enable the safe reuse of effluent for garden bed vegetation growth including native species. The natural environment is enhanced with this on-site wastewater treatment system through increased native vegetation on the household allotment and, in the wider environment, with reduced use of water resources.

The potential of this system to provide at the same time a cost effective common effluent drainage and wastewater reuse scheme is a significant advantage. This flexibility will become increasingly important as the high capital, operational and environmental costs of large centralised sewerage treatment plants become unaffordable and unacceptable.

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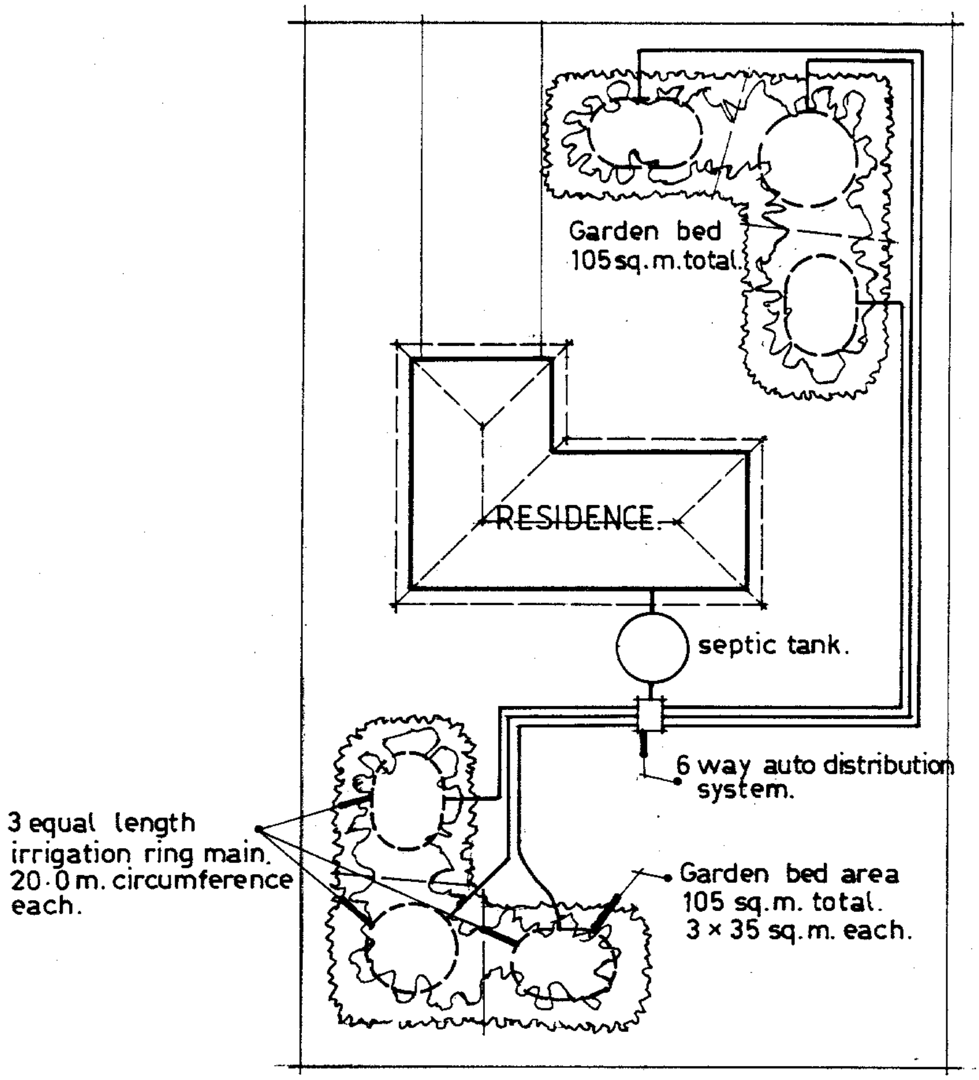
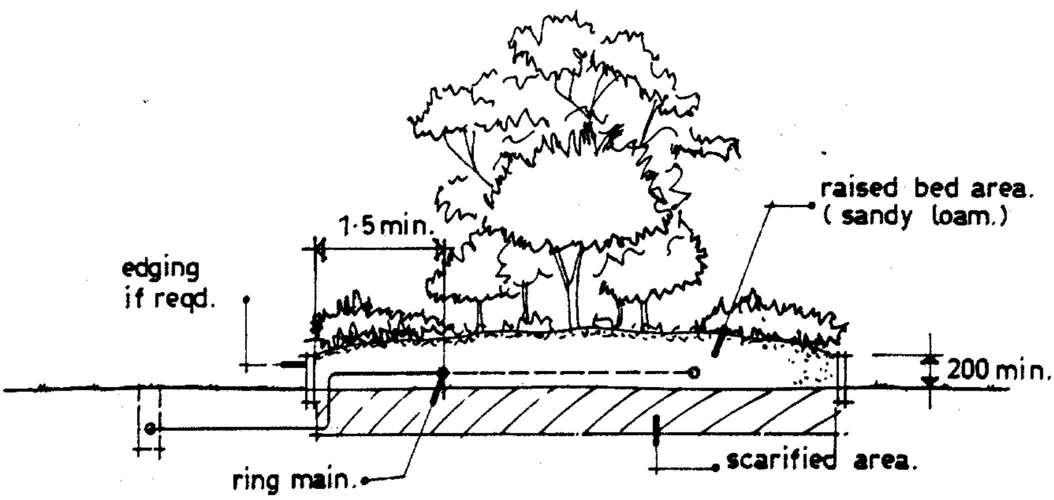
APPENDIX 1



SITE PLAN.



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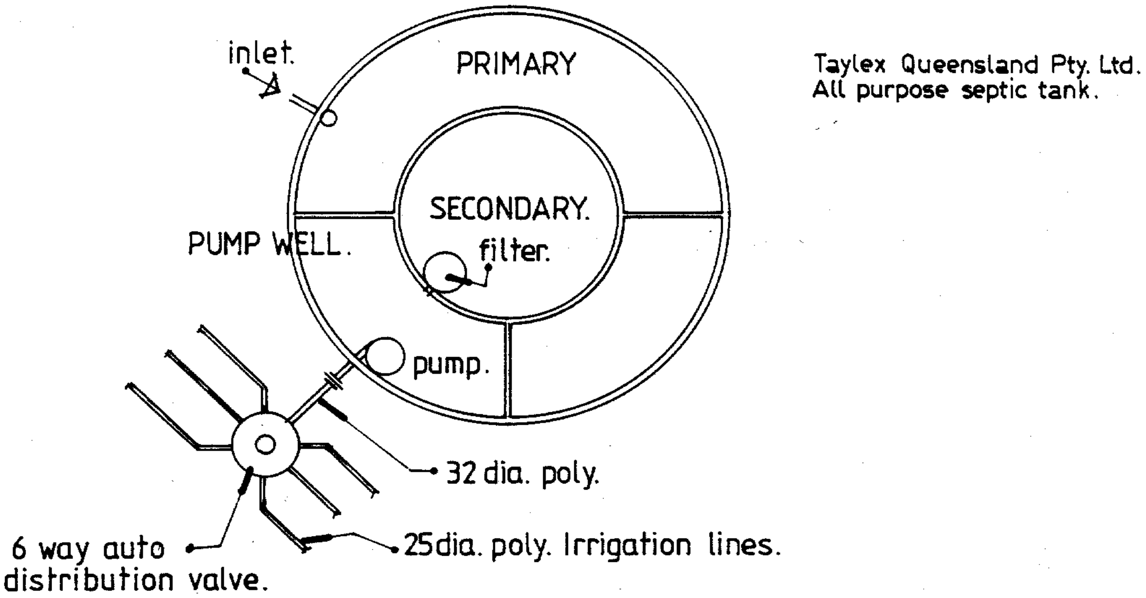
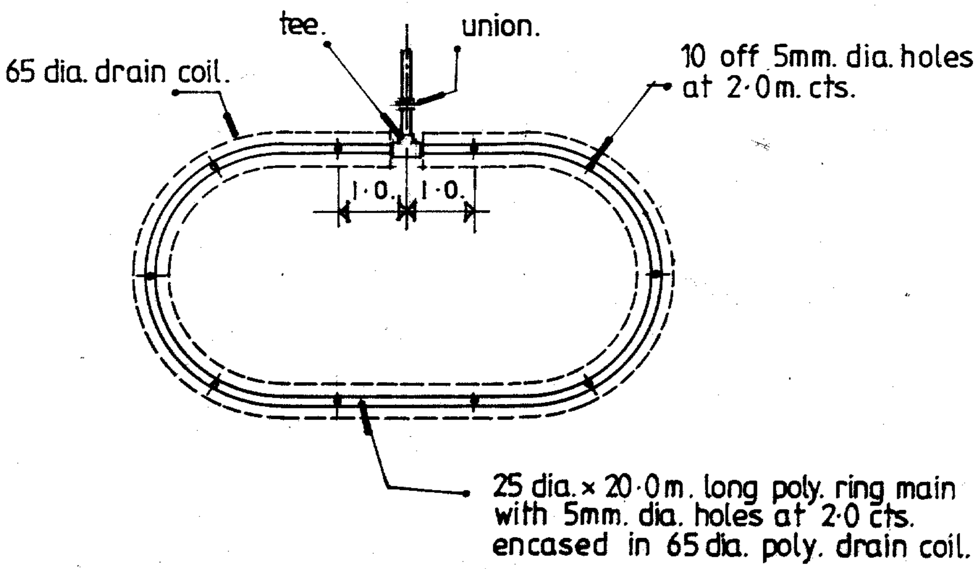


ARRANGEMENT SEPTIC TANK.



EFFLUENT DISPOSAL PIPING.

APPENDIX 2

PLANT VARIETIES SUITABLE FOR PERMANENTLY BOGGY SOILS

SEPTIC/SEWERAGE TRENCHES

Native Species Commonly Available for Beaudesert Shire

Large Canopy Trees (15-20m+)

Casuarina cunninghamiana	River She Oak
Eucalyptus botryoides	Bangalay
Eucalyptus camaldulensis	River Red Gum
Eucalyptus grandis	Flooded Gum
Eucalyptus robusta	Swamp Mahogany
Grevillea robusta	Silky Oak
Lophostemon confertus	Brush Box
Melia azedarach	White Cedar

Small To Medium Trees (6m – 15m Tall)

Callistemon salignus	White Bottlebrush
Callistemon viminalis	Weeping Bottlebrush
Casuarina equisetifolia	Horse Tail She Oak
Casuarina glauca	Swamp Oak
Elaeocarpus reticulatus	Blue Berry Ash
Eugenia smithii	Scrub Cherry
Hymenosporum flavum	Native Frangipani
Melaleuca bracteata (and forms)	White Cloud Tree
Melaleuca leucadendron (Broad and Fine Leaf)	Weeping Paperbark
Melaleuca linariifolia	Snow In Summer
Melaleuca quinquinervia (Red)	Broad Leaf Paperbark
Melaleuca quinquinervia (White)	Broad Leaf Paperbark
Melaleuca stypheloides	Prickly Paperbark
Tristania laurina	Water Gum

Small To Medium Shrubs (1.5-2m Tall)

Acacia floribunda	Gossamer Wattle
Baeckea imbricata	
Baeckea virgata	Twiggy Baeckea
Banksia robur	Swamp Banksia
Callicoma serratifolia	Black Wattle
Callistemon spp	Bottlebrushes
Callistemon citrinus	Bottlebrushes
Callistemon pinifolius	Bottlebrushes
Callistemon speciosus	Bottlebrushes
Leptospermum flavescens	Tea Tree
Melaleuca armillaris	Honey Braclet Myrtle
Melaleuca hypericifolia	
Melaleuca laterita	Robin Red Breast
Melaleuca thymifolia	Lace Flower Myrtle

Ground Covers/Rockery/Clumping Plants (To 1m)

Anigozanthos Flavidus	Kangaroo Paw
Brachycombe multifida	Native Daisy
Crinum pedunculatum	Swamp Lily
Dianella caerula	Blue Flax Lily
Ferns (All)	
Isotoma fluviatilis	
Lomandra longifolia	Matrush
Mentha austrlis	Native Mint
Pratia pedunculata	Pratia
Viola betonicifolia	Narrow Leaf Violet
Viola hederacea	Native Violet

Planting Instructions

Two garden beds layout – split the following total number of plants into each garden bed.

2 large canopy trees – 200mm pot size
8 small to medium trees – 140mm pot size
50 small to medium shrubs – 140mm pot size
40 ground cover clumping plants – 75mm tubes

Cluster shrubs of the same species and place clumping/ground cover plants near the outside edge of the garden beds.

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