

Site and Soil Assessment for On-site Effluent Disposal

**Lot 2, DP 1101252
12 David St, Gundaroo**

February 2016

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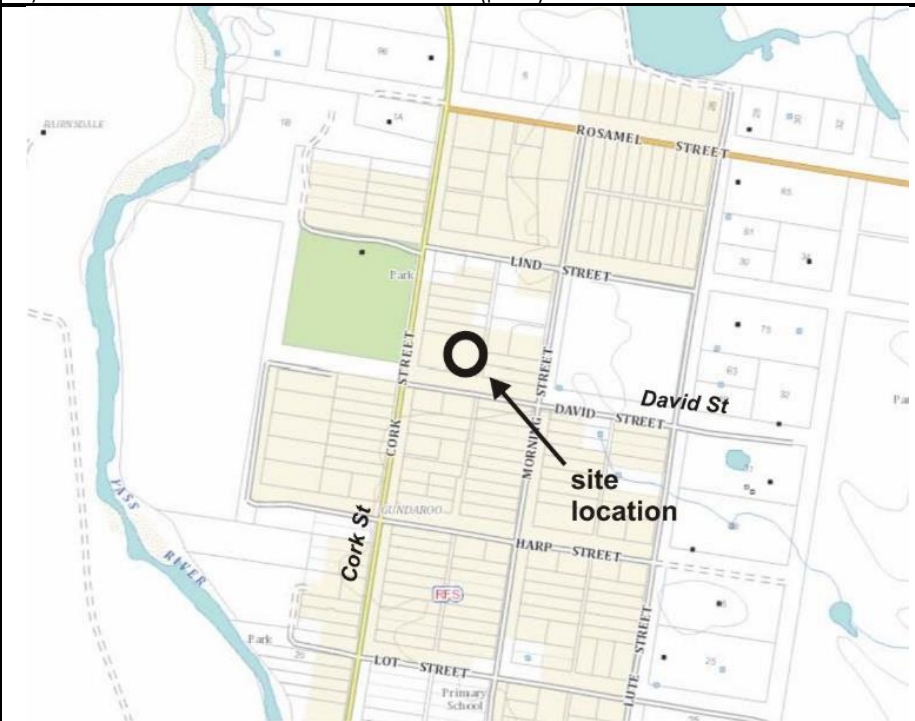
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Soil survey and assessment for forestry, agriculture, urban development; land degradation assessment;
catchment planning; soil conservation advice and planning; farm planning; land capability mapping
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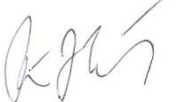

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Good management of effluent protects the environment and the value of your property. See pages 5 to 7 for key prescriptions for management of effluent

| Project Definition | |
|---------------------------|---|
| Overview | <p>The report provides direction for sustainable on-site effluent management for a new five bedroom dwelling. The site is somewhat constrained by the small lot area but there is a large area of land suited to drip irrigation onto established landscape plantings.</p> <p>The report also includes the AS2870 site classification (see page 4).</p> |
| Key References | <p>NSW Govt, 1998. <i>On-site Sewage Management for Single Households (The Silver Book)</i>.</p> <p>ANZ Standard 1547:2012 <i>On-site Domestic Wastewater Management</i>.</p> <p>Jenkins B. (2000). Soil landscapes of the Canberra 1:100,000 sheet. DLWC.</p> <p>Yass Valley Council LEP 2010.</p> |
| Reporting | <p>The report assesses land across the whole lot to determine suitability for on-site disposal of secondary treated effluent. The assessment is based on detailed description of the site and soil conditions and extensive experience in the general area.</p> <p>The assessment is presented in the pro forma from the Silver Book (NSW Govt 1998), and includes effluent management prescriptions (p5-6), site plan (p7) and photograph, with supporting information including nutrient balance, hydraulic balance and limitation tables (p8-9).</p> |
| Location |  |
| Terrain | Gently graded terrace within gently undulating terrain developed on old weathered alluvium. No drainage features or bores in vicinity. |
| Soils | See appendix 1 for soil profile description. Deep red chromosol comprising loam upper layer over clay subsoil, depth >100cm. |
| Constraints | <p>YVC LEP2013 maps site as groundwater vulnerable, see footnote page 3.</p> <p>Site is within 100yr flood level, see management prescriptions.</p> |

Site and Soil Evaluation

| Site Evaluator Details | |
|------------------------|---|
| Name Company | Peter Fogarty Soil and Land Conservation Consulting P/L |
| Phone Fax | 0409129608 61614062 |
| Date of Assessment | February 18, 2016 |
| Signature Date |   |

| Site Information | |
|---|--|
| Local Government Area | Yass Valley Shire Council |
| Address/locality | Lot 2, DP 1101252 12 David St, Gundaroo |
| Owner | Ben Thistleton |
| Developer | Above |
| Block configuration plans attached photo attached | 2500m ² yes yes |
| Intended water supply | Tank water |
| Expected wastewater volume (litres/day) | Assume 120l/pp /day, six potential occupants in five bedrooms, hence total daily design load of 720l/day. |
| Local experience | Systems in area operate adequately on appropriate soil and site conditions. Systems commonly malfunction due to lack of ongoing maintenance. System to be maintained regularly, in accordance with council regulations and prescriptions in this report. |

Looking across land designated for effluent dispersal, photo point shown on fig 1



| Site Assessment | |
|--|--|
| Climate | Warm summers with large evaporative deficit, cool winters with small evaporative deficit; median summer monthly rainfall for Canberra airport 49mm; median monthly winter rainfall 38mm; mean monthly summer evap. 177mm, mean monthly winter evap 60mm. |
| Rainfall water balance attached | NA |
| Land application area calculated | Yes |
| Wet weather storage calculation attached | NA |
| Flood potential: land application area above 1:20 yr flood land application area above 1:100 yr flood electrical components above 1:100 yr flood | Yes Yes System located in building pad, above flood level. |
| Exposure | Good exposure. |
| Slope | 1-2% |
| Landform | Gently graded terrace formed on old weathered alluvium |
| Run-on | Diversion drain not required for irrigation of effluent; ensure house site runoff does not drain across dispersal area |
| Seepage | None |
| Erosion Potential | Low due to adequate ground cover |
| Site drainage | Freely drained |
| Fill | None |
| Groundwater: Horizontal distance to groundwater well used for domestic supply Groundwater vulnerability map category Bores in area and purpose | None known within 250m Vulnerable on LEP 2103 maps, see footnote No bores in vicinity of lot or on lot |
| Buffer distance from dispersal area to: perennial rivers and creeks drainage lines other sensitive environments boundary of premises swimming pools buildings | Not applicable to site Not applicable to site None 1m from boundary NA 6m |
| Is there sufficient land area for: application system including buffers reserve application system | Yes Yes, ample room within land designated as suitable |
| Surface rock and outcrop | None |

¹ The groundwater table is typically located either at a depth in excess of 20m in the fractured hard rock aquifer system or in alluvial layers at depths of 10-20m, based on records from the NSW Groundwater database.

There is little likelihood of contamination of groundwater at these depths, given the deep cover of soil and alluvium, together with the low rate of effluent application. Groundwater contamination in villages typically results from poorly performing absorption trenches draining to bores located nearby, and contamination connecting to the groundwater system by draining down the bore casing. Effluent will be treated to a secondary standard and disinfected prior to dispersal at a low rate (~1.5mm/day) by surface drip irrigation. This will maximise the opportunity for vegetative utilisation, and minimise the risk of leaching. Additionally there are no bores on the lot or in the vicinity of the lot.

| Soil Assessment | |
|--|--|
| Depth to bedrock or hardpan | 100cm |
| Depth to high soil watertable | >150cm |
| Hydraulic loading rate | Silty clay loam upper layer to 50cm overlying clay subsoil. Weak in upper layer, moderate in loam subsoil 0.5-1.5m/day DIR of 4mm/day (see page 11); actual application rate is 1.5mm/day based on nutrient balance |
| soil texture | |
| soil structure | |
| permeability (from table M1 of ANZ Standard 1547:2012) | |
| recommended hydraulic loading for disposal system (from table M1 of ANZ Standard 1547:2012) | |
| Coarse fragments | 0 |
| Bulk density | Estimate 1.4 |
| pH (measured) | Surface 5.5, subsoil 5 (acid, no constraint) |
| Electrical conductivity dS/m¹ | Topsoil 0.08, subsoil 0.05 (low, no constraint) |
| Exchangeable sodium %¹ | Topsoil 4, subsoil 1 (low, no constraint) |
| Cation exchange capacity¹ | Topsoil 18, subsoil 11 (high, no constraint) |
| Phosphorous sorption capacity¹ | 6,000kg/ha (high, no constraint) |
| Geological features | None None |
| discontinuities | |
| fractured rock | |
| Soil landscape reference ¹ | Gundaroo, units 1 and 3 |
| Dispersiveness | Low in surface and subsoil (EAT 8, 3(1) respectively), no constraint |
| AS2870 Site Class (for in situ soil at house site) | M (moderately reactive) See explanatory notes in appendix 2. |

¹ extrapolated from Jenkins B. (2000). Soil landscapes of the Canberra 1:100,000 sheet. DLWC

| System Selection | |
|--|-----------------------------------|
| Consideration of connection to centralised sewerage system distance potential for future connection potential for reticulated water | >1km none none |
| Type of treatment system best suited | NSW Health accredited AWTS |
| Justification | Suitable site and soil conditions |
| Type land application system best suited | Surface drip irrigation |
| Justification | Suitable site and soil conditions |

| Effluent Management | |
|--------------------------|--|
| Management prescriptions | <p>Effluent Treatment System</p> <p>Effluent will be treated by a NSW Health accredited system capable of secondary standard treatment (see table 1).</p> <p>Ensure the pump has capacity to achieve the lift and required pressure for the irrigation system to operate effectively.</p> <p>The system will be located so the electrical components are above the 100yr flood level. This can most readily be achieved by located the system in the elevated building pad. Other solutions may also be suitable as long as the electricals are above flood level.</p> <p>Effluent dispersal</p> <p>A designated effluent dispersal area of 350m² will be located within land shown on fig 1 as suitable, taking into account the buffers specified on fig 1.</p> <p>Effluent is to be dispersed by drip irrigation onto an established area of landscape plantings. The bed should comprise as far as practical topsoil but can also include soil which will be excavated in the process of building.</p> <p>Based on a pump dose of 150l and pump cycle of 20min, The irrigation line should comprise 60 8l/hr drip emitters or 40 12l/hr emitters.</p> <p>The delivery line to the irrigation area from the treatment system will be buried at 300mm with a riser to connect to the effluent irrigation line.</p> <p>The delivery line for drip irrigation will incorporate a filter, either a disc filter or mesh filter. The filter will require quarterly cleaning.</p> <p>The dripper lines will be covered by a minimum of 10cm of mulch, such as tanbark.</p> <p>General management issues</p> <p>Vehicular access must be excluded from the irrigation area as they compact the soil, thereby reducing the infiltration rate and water holding capacity. As there will be no stock on the site, a fence will not be required around the dispersal area.</p> |

| | |
|--|--|
| | <p>Detergents low in phosphorous and sodium should be used as far as possible (see details in appendix) in order to protect the soil's capacity to absorb water and minimise nutrient loading.</p> <p>Sewerage treatment occurs a result of bacterial activity in the treatment tank. Do not put anti-bacterial products such as bleach, disinfectant and anti biotics into the sewerage system as they will significantly impair the effectiveness of sewerage treatment.</p> |
|--|--|

Table 1: NSW Health accredited secondary treatment systems

| AWTS | | |
|----------------------------------|---------------------------------------|----------------|
| AWTS Maintenance | Envirocycle 10NR | 62581378 |
| Bioseptic | Performa | 1300 658 111 |
| Clearwater Sewage and Watertanks | Biodigester II | 1300 132 760 |
| Earthsafe Environmental | Earthsafe ES10PC | 1300 327 847 |
| Eco Septic | Econocycle ENC 10-1, ENC 10-2 | 4774 1316 |
| Everhard Industries | Aqua Nova 10EP, NR, MBR10 | (02) 9757 2799 |
| Fuji Clean | Fuji Clean CE 1200, CRX 1500, CE 1500 | (07) 5580 0927 |
| Rainflow Stowater Solutions | Gardenmaster GM7100, MBR | (02) 4932 1011 |
| Icon Septech | Turbojet 2000 | 1800 181918 |
| Jowa Group | Biocycle Bio 7000 | (08) 8381 9100 |
| Krystel Kleer | Krystel Kleer ADV 5000 | 62581378 |
| Magnesium Tech | Waterboy Model 10, Model S | (07) 4055 1141 |
| Sun Coast Wastewater Management | Ozzie Kleen RP10 | 1300 360639 |
| Super Treat Systems | Super Treat SE 10 | 6235 0955 |
| Taylex Industries | Taylex DMS, ABS, Poly ABS | 07 34415200 |
| Ultra Clear Wastewater | Ultra Clear (3 models) | 1800 049911 |

See details at:

<http://www.health.nsw.gov.au/environment/domesticwastewater/Pages/default.aspx>

Fig 1: land suitable for effluent application



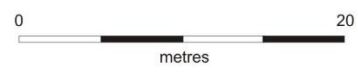
Photo point

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Soil profile



Land free of physical constraints for effluent dispersal: 350m² shown



designated buffers with dispersal area
6m from building
1m from driveway
1m from boundary

Site and Soil Limitation Assessment

The following two limitation tables are a standardised guide to the site and soil characteristics which may limit the suitability of the site for effluent disposal and which would require attention through specific management practices. The tables have been reproduced from *On-site Sewage Management for Single Households* (tables 4 and 6, Anon, 1998). The italicised categories represent site and soil conditions of the land covered in this report. The tables below show that the area has slight to moderate limitations with soil depth a severe limitation.

Site limitation assessment

| Site feature | Relevant system | Minor limitation | Moderate limitation | Major limitation | Restrictive feature |
|-----------------------|------------------------------|---|-----------------------------------|---|--|
| Flood potential | All land application systems | > 1 in 20 yrs | | Frequent, below 1 in 20 yrs | Transport in wastewater off site |
| | All treatment systems | components above 1 in 100 yrs | | Components below 1 in 100 yrs | Transport in wastewater off site, system failure |
| Exposure | All land application systems | High sun and wind exposure | | Low sun and wind exposure | Poor evapo-transpiration |
| Slope % | Surface irrigation | 0-6 | 6-12 | >12 | Runoff, erosion potential |
| | Sub-surface irrigation | 0-10 | 10-20 | >20 | Runoff, erosion potential |
| | Absorption | 0-10 | 10-20 | >20 | Runoff, erosion potential |
| Landform | All systems | Hillcrests, convex sideslopes and plains | Concave sideslopes and footslopes | Drainage plains and incised channels | Groundwater pollution hazard, resurfacing hazard |
| Run-on and seepage | All land application systems | None-low | Moderate | High, diversion not practical | Transport of wastewater off site |
| Erosion potential | All land application systems | No sign of erosion potential | | Indications of erosion eg rills, mass failure | Soil degradation and off-site impact |
| Site drainage | All land application systems | No visible signs of surface dampness | | Visible signs of surface dampness | Groundwater pollution hazard, resurfacing hazard |
| Fill | All systems | No fill | Fill present | | Subsidence |
| Land area | All systems | Area available | | Area not available | Health and pollution risk |
| Rock and rock outcrop | All land application systems | <10% | 10-20% | >20% | Limits system performance |
| Geology | All land application systems | None | | Major geological discontinuities, fractured or highly porous regolith | Groundwater pollution hazard |

Soil limitation assessment

| Soil feature | Relevant system | Minor limitation | Moderate limitation | Major limitation | Restrictive feature |
|---|---|-----------------------------------|---------------------|------------------------|---|
| Depth to bedrock or hardpan (m) | Surface and sub surface irrigation | > 1.0 | .5-1.0 | < 0.5 ¹ | Restricts plant growth |
| | Absorption | > 1.5 | 1.0-1.5 | < 1.0 | Groundwater pollution hazard |
| Depth to seasonal water table (m) | Surface and sub surface irrigation | > 1.0 | 0.5-1.0 | < 0.5 | Groundwater pollution hazard |
| | Absorption | > 1.5 | 1.0-1.5 | < 1.0 | Groundwater pollution hazard |
| Permeability Class | Surface and sub surface irrigation | 2b, 3 and 4 | 2a, 5 | 1 and 6 | Excessive runoff and waterlogging Percolation |
| | Absorption | 3, 4 | | 1, 2, 5, 6 | |
| Coarse fragments % | All systems | 0-20 | 20-45 | >40 | Restricts plant growth, affects trench installation |
| Bulk density (g/cc) SL L, CL C | All land application systems | < 1.8 < 1.6 < 1.4 | | > 1.8 > 1.6 >1.4 | restricts plant growth, indicator of permeability |
| pH | All land application systems | > 6.0 | 4.5-6.0 | - | Reduces plant growth |
| Electrical conductivity (dS/m) | All land application systems | <4 | 4-8 | >8 | Restricts plant growth |
| Sodicity (ESP) | Irrigation 0-40cm; absorption 0-1.2mtr | 0-5 | 5-10 | > 10 | Potential for structural degradation |
| CEC mequiv/100g | Irrigation systems | > 15 | 5-15 | < 5 | Nutrient leaching |
| P sorption kg/ha | All land application systems | > 6000 | 2000-6000 | < 2000 | Capacity to immobilise P |
| Aggregate stability | All land application systems | Classes 3-8 | class 2 | class1 | Erosion hazard |

Sizing of Irrigation Area

The irrigation area size has been evaluated from the water balance, nitrogen balance and phosphorous balance. The largest area so determined represents the sustainable area for effluent irrigation. The balances below assume an effluent generation rate for a five bedroom dwelling of 720l/day.

Water Balance: $A = Q \text{ (l/day)}/\text{DIR (mm/day)}$;
where $Q = 720\text{l/day}$; $\text{DIR} = 4\text{mm/day}$ (from ANZ Standard 1547:2000)
 $A = 720/4 = 180\text{m}^2$

Nitrogen balance: $A = Q \text{ (l/day)} \times \text{TN (mg/l)}/L_n$ (critical loading of TN, $\text{mg/m}^2/\text{day}$)
 $Q = 720\text{l/day}$; $\text{TN} = 25\text{mg/l}$ (from Silver Book);

Assume 20% loss by denitrification; $25\text{mg/l} - (25 \times .2) = 20\text{mg/l}$
 $L_n = 15,000\text{mg/m}^2/\text{yr}$ (ie 150kg/ha/yr for introduced grass species)
 $A = 720 \times 20 \times 365/15,000 = 350\text{m}^2$

Phosphorous balance: P sorption capacity in upper 50cm
 $P_{\text{sorb}} = 3,000\text{kg/ha} = .3\text{kg/m}^2$

P uptake for design period of 50 years
 $P_{\text{uptake}} = 4\text{mg/m}^2/\text{day} \times 365 \times 50 = .073\text{kg/m}^2$

P generated over 50yr design period
 $P_{\text{gen}} = 10\text{mg/l} \times 720 \times 365 \times 50 = 131\text{kg}$

$A = P_{\text{gen}}/(P_{\text{uptake}} + P_{\text{sorb}}) = 131/ (.3 + .073) = 351\text{m}^2$

Thus the effluent dispersal area of **350m²** accounts for the phosphorous, nitrogen and water balances.

Appendix 1: Soil Profile Description

| Soil classification | Depth (cm) | Properties |
|---------------------|------------|--|
| Red chromosol | 0-5 | A1 dark grey brown organic rich loam, whole coloured, no gravel or stone, weak crumb structure; dry firm consistence, high content fine roots, gradual boundary to |
| | 5-50 | B1 light reddish brown silty loam, no stone or gravel, whole coloured, weak coarse blocky structure, dry firm consistence, non plastic, clear boundary to |
| | 50-100 | B2: reddish brown light clay, whole coloured, moderate grading to strong fine subangular blocky structure, dry very firm consistence, plastic, no gravel or stone; soil continues. |

Soil profile augered at the site



Apendix 2: Useful General Information

DO

- ✓ Learn how your sewage management system works and its operational and maintenance requirements.
- ✓ Learn the location and layout of your sewage management system.
- ✓ Have your AWTS (if installed) inspected and serviced four times per year by an approved contractor. Other systems should be inspected at least once every year. Assessment should be applicable to the system design.
- ✓ Keep a record of desludgings, inspections, and other maintenance.
- ✓ Have your septic tank or AWTS desludged every three years to prevent sludge build up, which may 'clog' the pipes.
- ✓ Conserve water. Conservative water use around the house will reduce the amount of wastewater which is produced and needs to be treated.
- ✓ Discuss with your local council the adequacy of your existing sewage management system if you are considering house extensions for increased occupancy.

DON'T

- ✗ Don't let children or pets play on land application areas.
- ✗ Don't water fruit and vegetables with effluent.
- ✗ Don't extract untreated groundwater for cooking and drinking.
- ✗ Don't put large quantities of bleaches, disinfectants, whiteners, nappy soakers and spot removers into your system via the sink, washing machine or toilet.
- ✗ Don't allow any foreign materials such as nappies, sanitary napkins, condoms and other hygiene products to enter the system.
- ✗ Don't put fats and oils down the drain and keep food waste out of your system.
- ✗ Don't install or use a garbage grinder or spa bath if your system is not designed for it.

ON-SITE SEWAGE MANAGEMENT SYSTEMS

If you live in or rent a house that is not connected to the main sewer then chances are that your yard contains an on-site sewage management system. If this is the case then you have a special responsibility to ensure that it is working as well as it can.

The aim of this pamphlet is to introduce you to some of the most popular types of on-site sewage management systems and provide some general information to help you maintain your system effectively. You should find out what type of system you have and how it works.

More information can be obtained from the pamphlets:

Your Septic System
Your Aerated Wastewater Treatment System
Your Composting Toilet
Your Land Application Area

You can get a copy of these pamphlets from your local council or the address marked on the back of this pamphlet.

It is important to keep in mind that maintenance needs to be performed properly and regularly. Poorly maintained on-site sewage management systems can significantly affect you and your family's health as well as the local environment.

What is an on-site sewage management system?

A domestic on-site sewage management system is made up of various components which - if properly designed, installed and maintained - allow the treatment and utilisation of wastewater from a house, completely within the boundary of the property.

Wastewater may be blackwater (toilet waste), or greywater (water from showers, sinks, and washing machines), or a combination of both.

Reducing water usage

Reducing water usage will lessen the likelihood of problems such as overloading with your septic system. Overloading may result in wastewater backing up into your house, contamination of your yard with improperly treated effluent, and effluent from your system contaminating groundwater or a nearby waterway.

Your sewage management system is also unable to cope with large volumes of water such as several showers or loads of washing over a short period of time. You should try to avoid these 'shock loads' by ensuring water use is spread more evenly throughout the day and week.

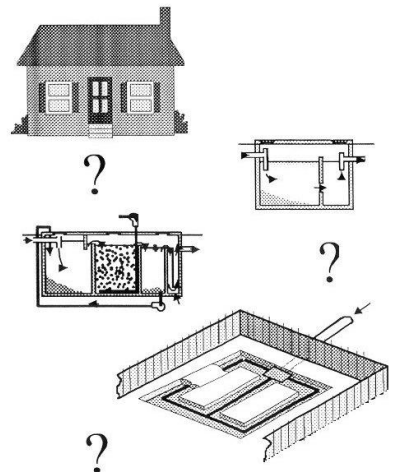
HELP PROTECT YOUR HEALTH AND THE ENVIRONMENT

Poorly maintained sewage management systems are a serious source of water pollution and may present health risks, cause odours and attract vermin and insects.

By looking after your management system you can do your part in helping to protect the environment and the health of you and your community.

For more information please contact:

Managing Wastewater In Your Backyard



Partial on-site systems - eg. pump out and common effluent systems (CES) - also exist. These usually involve the preliminary on-site treatment of wastewater in a septic tank, followed by collection and transport of the treated wastewater to an off-site management facility. Pump out systems use road tankers to transport the effluent, and CES use a network of small diameter pipes.

How does an on-site sewage management system work?

For complete on-site systems there are two main processes:

1. treatment of wastewater to a certain standard
2. its application to a dedicated area of land.

The type of application permitted depends on the quality of treatment, although you should try to avoid contact with all treated and untreated wastewater, and thoroughly wash affected areas if contact does occur.

Treatment and application can be carried out using various methods:

Septic Tank

Septic tanks treat both greywater and blackwater, but they provide only limited treatment through the settling of solids and the flotation of fats and greases. Bacteria in the tank break down the solids over a period of time. Wastewater that has been treated in a septic tank can only be applied to land through a covered soil absorption system, as the effluent is still too contaminated for above ground or near surface irrigation.

AWTS

Aerated wastewater treatment systems (AWTS) treat all household wastewater and have several treatment compartments. The first is like a septic tank, but in the second compartment air is mixed with the wastewater to assist bacteria to break down solids. A third compartment allows settling of more solids and a final chlorination contact chamber allows disinfection. Some AWTS are constructed with all the compartments inside a single tank. The effluent produced may be surface or sub-surface irrigated in a dedicated area.

Composting Toilets

Composting toilets collect and treat toilet waste only. Water from the shower, sinks and the washing machine needs to be treated separately (for example in a septic tank or AWTS as above). The compost produced by a composting toilet has special requirements but is usually buried on-site.

These are just some of the treatment and application methods available, and there are many other types such as sand filter beds, wetlands, and amended earth mounds. Your local council or the NSW Department of Health have more information on these systems if you need it.

Regulations and recommendations

The NSW Department of Health determines the design and structural requirements for treatment systems for single households. Local councils are primarily responsible for approving the installation of smaller domestic septic tank systems, composting toilets and AWTSs in their area, and are also responsible for approving land application areas. The NSW Environment Protection Authority approves larger systems.

The design and installation of on-site sewage management systems, including plumbing and drainage, should only be carried out by suitably qualified or experienced people. Care is needed to ensure correct sizing of the treatment system and application area.

Heavy fines may be imposed under the Clean Waters Act if wastewater is not managed properly.

Keeping your on-site sewage management system operating well

What you put down your drains and toilets has a lot to do with how well your system performs. Maintenance of your sewage management system also needs to be done well and on-time. The following is a guide to the types of things you should and should not do with your system.

Foundation Maintenance and Footing Performance: A Homeowner's Guide



CSIRO
BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction

There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion

All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation

This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil

All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure

This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

| Class | Foundation |
|--------|---|
| A | Most sand and rock sites with little or no ground movement from moisture changes |
| S | Slightly reactive clay sites with only slight ground movement from moisture changes |
| M | Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes |
| H | Highly reactive clay sites, which can experience high ground movement from moisture changes |
| E | Extremely reactive sites, which can experience extreme ground movement from moisture changes |
| A to P | Filled sites |
| P | Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise |

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpend).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

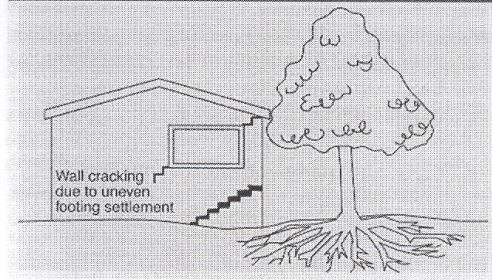
Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage



As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures

Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures

Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.

Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.

- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing

Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage

In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish water table height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

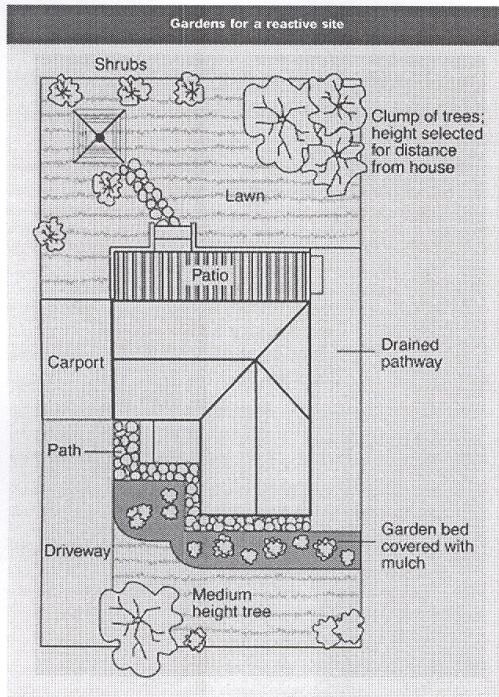
Protection of the building perimeter

It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

| Description of typical damage and required repair | Approximate crack width limit (see Note 3) | Damage category |
|---|---|-----------------|
| Hairline cracks | <0.1 mm | 0 |
| Fine cracks which do not need repair | <1 mm | 1 |
| Cracks noticeable but easily filled. Doors and windows stick slightly | <5 mm | 2 |
| Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired | 5–15 mm (or a number of cracks 3 mm or more in one group) | 3 |
| Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted | 15–25 mm but also depend on number of cracks | 4 |



- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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