On-site Wastewater Management Training Course

# Soils; Soil Testing

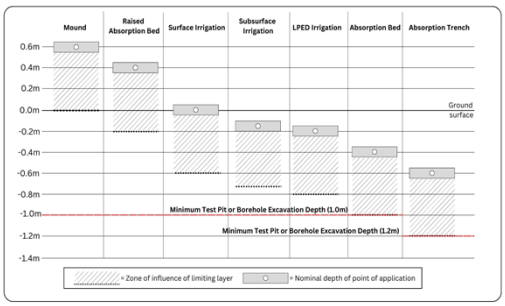


## Why test soil?

- Testing of soil physical and chemical properties
- Undertaken to support selection and sizing of land application systems
- Require an agronomic assessment of soils rather than an engineering assessment
- Need to understand how soils and wastewater interact
- Need to assess the capacity of soil to further treat wastewater
- Need to minimise the impact of wastewater on receiving waters; groundwater and surface water
- Free draining soil is capable of achieving secondary treatment



## Separation / Clearance Depth






## Soil Testing Methods

- Investigate the effect of wastewater application on soil permeability
  - Contrast behaviour of soil when exposed to clean and dirty/soapy water
- Undertake a number of tests either in the field or the laboratory:
  - Determining soil structural stability (Emerson test)
  - Measuring electrical conductivity (EC)
  - Measuring pH
  - Determining soil texture
- Description of the soil profile



## Comparative Column Tests

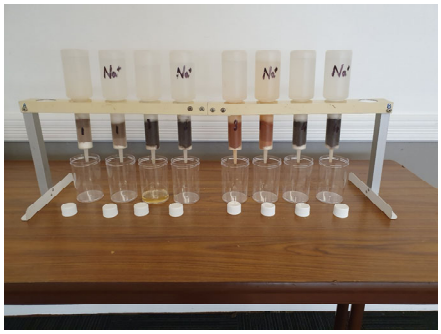
- Illustrates how readily effluent with a high concentration of sodium salts can affect the permeability of soil, both on first exposure to effluent and over time
  - Comparative pairs of soil columns treated with clean water and typical laundry water with laundry detergent dissolved 2mg/L

Consider:

- Differences in permeability due to effluent chemistry
- Differences in leachate colour due to particulate (colloid) movement
- Differences between soil textures



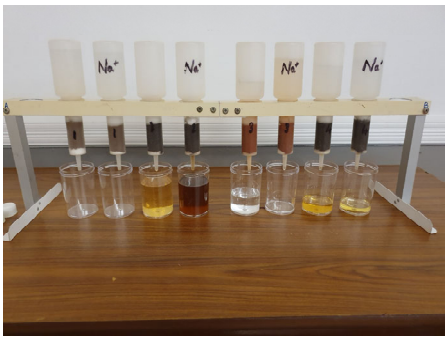
## Comparative Column Tests 0 hours



## Comparative Column Tests 3 hours




## Comparative Column Tests 7 hours






## Comparative Column Tests 22 hours



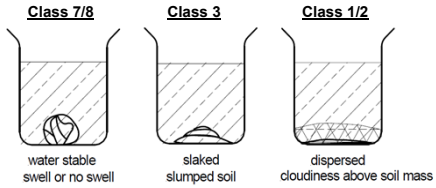

## Soil Stability

- Soils may become structurally unstable when exposed to low salinity water (EC<1dSm$^{-1}$)
- Can present a significant problem when exposed to domestic wastewater
- Stability of a soil can be investigated by exposing an air-dried ped to low salinity water
- Varying responses:
  - Stable
  - Slake – disintegrate/fall apart
  - Disperse – colloidal material goes into suspension (appears cloudy)
- Increased dispersibility reduces permeability



## Soil Structural Stability

- Emerson test (modified)
  - Place an air dried ped of soil in a petri-dish of deionised water
  - Examine after one hour
- Observations:



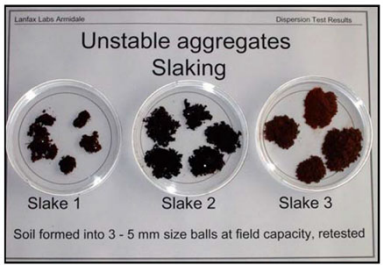



## Soil Structural Stability

- Class 7/8
- Surface soils with adequate organic matter
- Generally good for effluent dispersal

## Soil Structural Stability

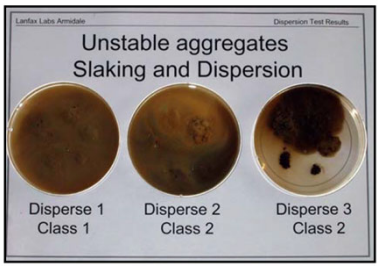
- Class 3
- Common in deeper soils with limited organic matter
- Generally not problematic for effluent dispersal






## Soil Structural Stability

- Class 1/2
- Colloids block pores and reduce permeability ($K_{sat}$)
- Ameliorate using gypsum or lime (if acid soil)






## Soil pH and EC

- pH measured from a 1:5 soil:water suspension
- pH is a measure of soil acidity
- Under acid conditions ions which are toxic to plans can be released impacting vegetation in the land application area
- Under alkaline conditions nitrogen becomes less available and calcium and magnesium precipitate out of soil solution
- EC measured from a 2:5 soil:water suspension
- EC is a measure of the salt content, which again can adversely impact vegetation in the land application area



## Soil pH and EC

- pH measured using pH test strips or hand held meter
- EC measured using hand held meter



## Determining Soil Texture

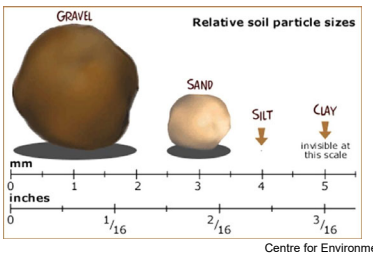
| Soil Category | Texture Group | Texture Grades |
|---|---|---|
| 1 | Sands | sand, loamy sand, clayey sand |
| 2 | Sandy loams | sandy loam, fine sandy loam |
| 3 | Loams | loam, silty loam, loamy silt |
| 4 | Clay loams | sandy clay loam, clay loam, silty clay loam, fine sandy clay loam, sandy clay |
| 5 | Light clays | silty clay, light clay, light medium clay |
| 6 | Medium-heavy clays | medium clay, heavy clay |



## Soil Particle Size and Texture

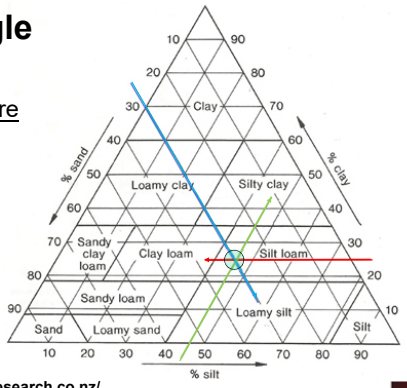
Soil textures are classified according to the relative proportions of different particle sizes being present:

- sand (0.02-2mm),
- silt (0.002-0.02mm)
- clay (<0.002mm)



## Soil Textural Triangle

Silt loam texture
- 25% clay
- 45% silt
- 30% sand

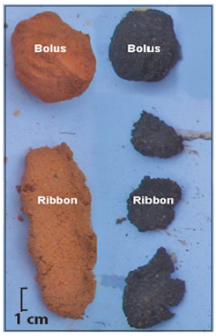



https://soils.landcareresearch.co.nz/



## Field Textural Determination

- 'Ribbon Test' developed to provide a fast and repeatable method for field description of in-situ soil texture
  - subjective test
  - requires practice and skill development
- Determine relative proportions of silt, sand clay fractions based on moistened bolus
- Used to assess soil hydraulic capacity and infer design loading rate (DLR)






## Ribbon Test

- Dried and sieved (<2mm) sample of soil assessed using manual manipulation of 'bolus'



## Field Properties

- Method used to determine the approximate clay content of the soil sample for the purpose of classification to AS/NZS 1547
- Other indicators important:
  - Plasticity / Stickiness
  - Shear resistance
  - Stain
  - Feel

TABLE E1
ASSESSMENT OF SOIL TEXTURES

| Soil category | Classification | Properties | Typical clay content% (see Note) |
|---|---|---|---|
| 1 | Sand | Very little to no coherence; cannot be moulded; single grains stick to fingers | Less than 5 |
| 2 | Loamy sand | Slight coherence; forms a fragile cast that just bears handling; gives a very short (5 mm) ribbon that breaks easily; discolours the fingers | 5 – 10 |
| | Sandy loam | Forms a cast but will not roll into a coherent ball; individual sand grains can be seen and felt; gives a ribbon 15 – 25 mm long | 10 – 20 |
| 3 | Fine sandy loam | As for sandy loams, except that individual sand grains are not visible, although they can be heard and felt; gives a ribbon 15 – 25 mm long | 10 – 20 |
| | Loam | As for sandy loams but cast feels spongy, with no obvious sandiness or silkiness; may feel greasy if much organic matter is present; forms a thick ribbon about 25 mm long | 10 – 25 |
| | Silty loam | As for loams but not spongy; very smooth and silky; will form a very thin ribbon 25 mm long and dries out rapidly | 10 – 25 |
| 4 | Sandy clay loam | Can be rolled into a ball in which sand grains can be felt; forms a ribbon 25 – 40 mm long | 20 – 30 |
| | Fine sandy clay | As for sandy clay loam, except that individual sand grains loam are not visible although they can be heard and felt; forms a ribbon 40 – 50 mm long | 20 – 30 |
| | Clay loam | Can be rolled into a ball with a rather spongy feel; slightly plastic; smooth to manipulate; will form a ribbon 40 – 50 mm long | 25 – 35 |
| | Silty clay loam | As for clay loams but not spongy; very smooth and silky; will form a ribbon about 40 – 50 mm long; dries out rapidly | 25 – 35 |
| 5 | Sandy clay | Forms a plastic ball in which sand grains can be seen, felt or heard; forms a ribbon 50 – 75 mm long | 35 – 45 |
| | Light clay | Smooth plastic ball that can be rolled into a rod; slight resistance to shearing between thumb and forefinger; forms a ribbon 50 – 75 mm long | 35 – 40 |
| | Silty clay | As for light clay but very smooth and silky; will form a ribbon about 50 – 75 mm long but very fragmentary; dries out rapidly | 40 – 50 |
| 6 | Medium clay | Smooth plastic ball, handles like plasticine and can be moulded into rods without fracture; some resistance to ribboning, forms a ribbon 75 mm or more long | 40 – 55 |
| | Heavy clay | Smooth plastic ball that handles like stiff plasticine; can be moulded into rods without fracture; firm resistance to ribboning; forms a ribbon 75 mm or more in length | 50 or more |

NOTE: The typical clay content figures are included for information only.



## Soil Structure

- Arrangement of soil particles into natural aggregates (peds)

- Describes the distinctness, size and shape of peds
- Described in terms of structureless, massive, weak (peds indistinct), moderate or strong structure (peds distinct)

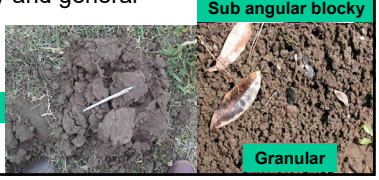


## Soil Structure

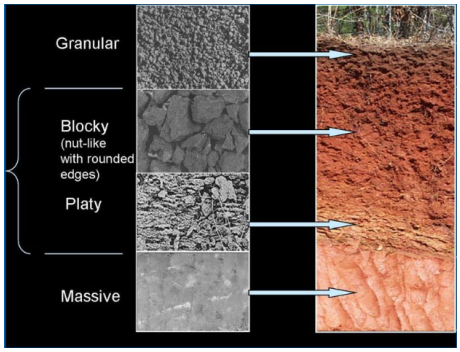
- Should be described from a 'fresh' vertical exposure
- CANNOT be assessed from an augered hole
- Soil structure affects; permeability, aeration, drainage, erosivity, surface condition, stability and general soil productivity



Drop Test Method



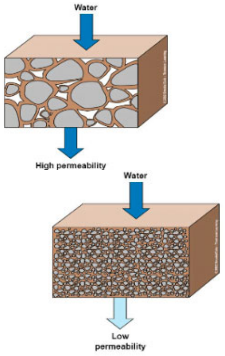
## Soil Structure






## Water in Soil - Permeability

- Relationship exists between soil texture and structure and indicative clean water permeability - see Tables 5.2 in AS/NZS 1547:2012
- Typically coarser grained soils have higher $K_{sat}$ than fine grained; some fine-grained soils can have higher $K_{sat}$ due to structure such as cracking






## Water in Soil - Permeability

| Texture Group | Typical Permeability $K_{sat}$ (m/d) |
|---|---|
| Gravels and sands | > 3.0 |
| Sandy loams | 1.4 – 3.0 |
| Loams | 0.5 – 1.5 |
| Clay loams | 0.06 – 1.5 |
| Light clays | < 0.06 – 0.5 |
| Medium-heavy clays | < 0.06 |

- Values based on movement of water not effluent through soil
- Use tables in AS/NZS1547 to select appropriate DLR / DIR for preferred land application system, based on determined soil category



## Soil Loading Rates

- Design loading rates / design irrigation rates assigned based on assessment of:
  - soil texture and structure
  - other factors (e.g. soil stability)
- AS/NZS1547:2012 loading tables:
  - Table L1 DLRs for trenches, beds and ETS beds
  - Table M1 DIRs for irrigation systems and Low Pressure Effluent Distribution (LPED) systems
  - Table N1 DLRs for mounds.



## Description of Soil Profile

- Graphic log
- Horizon ID
- Horizon thickness/depth
- Texture
- Structure
- Colour
- Mottles
- Coarse fragments
- Moisture condition
- Photograph

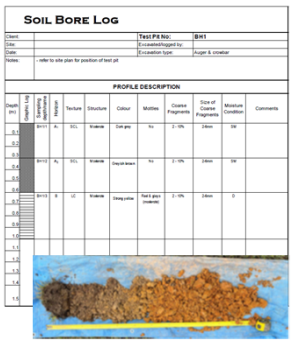


**TABLE L1**

**RECOMMENDED DESIGN LOADING RATES FOR TRENCHES AND BEDS**

| Soil category | Soil texture | Structure | Indicative permeability ($K_{sat}$)(m/d) | Design loading rate (DLR) (mm/d) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Trenches and beds | | | ETA/ETS beds and trenches |
| | | | | Primary treated effluent | | Secondary treated effluent | |
| | | | | Conservative rate | Maximum rate | | |
| 1 | Gravels and sands | Structureless (massive) | > 3.0 | 20 (see Note 1) | 35 (see Note 1) | 50 (see Note 1) | (see Note 4) |
| 2 | Sandy loams | Weakly structured | > 3.0 | 20 (see Note 1) | 30 (see Note 1) | 50 (see Note 1) | |
| | | Massive | 1.4 – 3.0 | 15 | 25 | 50 | |
| 3 | Loams | High/ moderate structured | 1.5 – 3.0 | 15 | 25 | 50 | |
| | | Weakly structured or massive | 0.5 – 1.5 | 10 | 15 | 30 | |
| 4 | Clay loams | High/ moderate structured | 0.5 – 1.5 | 10 | 15 | 30 | 12 |
| | | Weakly structured | 0.12 – 0.5 | 6 | 10 | 20 | 8 |
| | | Massive | 0.06 – 0.12 | 4 | 5 | 10 | 5 |
| 5 | Light clays | Strongly structured | 0.12 – 0.5 | 5 | 8 | 12 | 8 |
| | | Moderately structured | 0.06 – 0.12 | (see Notes 2 & 3) | 5 | 10 | 5 (see Notes 2, 3, & 5) |
| | | Weakly structured or massive | < 0.06 | | | 8 | |
| 6 | Medium to heavy clays | Strongly structured | 0.06 – 0.5 | | | | |
| | | Moderately structured | < 0.06 | | | | |
| | | Weakly structured or massive | < 0.06 | | | | |

NOTES:

1 The treatment capacity of the soil and not the hydraulic capacity of the soil or the growth of the clogging layer govern the effluent loading rate in Category 1 and weakly structured Category 2 soils. Land application systems in these soils require design by a suitably qualified and experienced person, and distribution techniques to help achieve even distribution of effluent over the full design surface (see L6.2 and Figure L4 for recommended discharge method by discharge control trench). These soils have low nutrient retention capacities, often allowing accession of nutrients to groundwater.

2 To enable use of such soils for on-site wastewater land application systems, special design requirements and distribution techniques or soil modification procedures will be necessary. For any system designed for these soils, the effluent absorption rate shall be based upon soil permeability testing. Specialist soils advice and special design techniques will be required for clay dominated soils having dispersive (sodic) or shrink/swell behaviour. Such soils shall be treated as Category 6 soils. In most situations, the design will need to rely on more processes than just absorption by the soil.

3 If $K_{sat}$ < 0.06 m/d, a full water balance for the land application can be used to calculate trench/bed size (see Appendix Q).

4 ETA/ETS systems are not normally used on soil Categories 1 to 3.

5 For Category 6 soils ETA/ETS systems are suitable only for use with secondary treated effluent.

(Source: AS/NZS 1547:2012 Standards Australia)

**TABLE M1**

**RECOMMENDED DESIGN IRRIGATION RATE (DIR) FOR IRRIGATION SYSTEMS**

| Soil Category (see Note 1) | Soil texture | Structure | Indicative permeability ($K_{sat}$) (m/d) | Design irrigation rate (DIR) (mm/day) | | |
|---|---|---|---|---|---|---|
| | | | | Drip irrigation | Spray irrigation | LPED irrigation |
| 1 | Gravels and sands | Structureless (massive) | > 3.0 | 5 (see Note 2) | 5 | (see Note 3) |
| 2 | Sandy loams | Weakly structured massive | > 3.0 | | | 4 |
| | | | 1.4 – 3.0 | | | |
| 3 | Loams | High/ moderate structured | 1.5 – 3.0 | 4 (see Note 1) | 4 | 3.5 |
| | | Weakly structured or massive | 0.5 – 1.5 | | | |
| 4 | Clay loams | High/ moderate structured | 0.5 – 1.5 | 3.5 (see Note 1) | 3.5 | 3 |
| | | Weakly structured | 0.12 – 0.5 | | | |
| | | Massive | 0.06 – 0.12 | | | |
| 5 | Light clays | Strongly structured | 0.12 – 0.5 | 3 (see Note 1) | 3 | 2.5 (see Note 4) |
| | | Moderately structured | 0.06 – 0.12 | | | |
| | | Weakly structured or massive | < 0.06 | | | |
| 6 | Medium to heavy clays | Strongly structured | 0.06 – 0.5 | 2 (see Note 2) | 2 | (see Note 3) |
| | | Moderately structured | < 0.06 | | | |
| | | Weakly structured or massive | < 0.06 | | | |

NOTES:

1 For Category 3 to 5 soils (loams to light clays), the drip irrigation system needs to be installed in an adequate depth of topsoil (in the order of 150 – 250 mm of *in situ* or imported good quality topsoil) to slow the soakage and assist with nutrient reduction.

2 For Category 1, 2, and 6 soils, the drip irrigation system has a depth of 100 – 150 mm in good quality topsoil (see CM1 and M3.1).

3 LPED irrigation is not advised for Category 1 or Category 6 soils – drip irrigation of secondary effluent is the preferred irrigation method.

4 LPED irrigation for Category 5 soils needs a minimum depth of 250 mm of good quality topsoil (see M5 and CM7.1).

(Source: AS/NZS 1547:2012 Standards Australia)

**TABLE N1**

**RECOMMENDED MOUND DESIGN LOADING RATES**

| Soil Category | Soil texture | Structure | Indicative permeability ($K_{sat}$)(m/d) | Design loading rate (DLR) (mm/d) |
|---|---|---|---|---|
| 1 | Gravels and sands | Structureless (massive) | > 3.0 | 32 |
| 2 | Sandy loams | Weakly structured | > 3.0 | 24 |
| | | Massive | 1.4 – 3.0 | 24 |
| 3 | Loams | High/ moderate structured | 1.5 – 3.0 | 24 |
| | | Weakly structured or massive | 0.5 – 1.5 | 16 |
| 4 | Clay loams | High/ moderate structured | 0.5 – 1.5 | 16 |
| | | Weakly structured | 0.12 – 0.5 | 8 |
| | | Massive | 0.06 – 0.12 | 5 (see Note) |
| 5 | Light clays | Strongly structured | 0.12 – 0.5 | 8 |
| | | Moderately structured | 0.06 – 0.12 | 5 (see Note) |
| | | Weakly structured or massive | < 0.06 | |
| 6 | Medium to heavy clays | Strongly structured | 0.06 – 0.5 | |
| | | Moderately structured | < 0.06 | |
| | | Weakly structured or massive | < 0.06 | |

NOTE: To enable use of such soils for on-site wastewater land application, special design requirements and distribution techniques or soil modification procedures will be necessary. For any system designed for these soils, the effluent absorption rate shall be based upon soil permeability testing. Specialist soils advice and special design techniques will be required for clay dominated soils having dispersive (sodic) or shrink/swell behaviour. Such soils shall be treated as Category 6 soils. In most situations, the design will need to rely on more processes than just absorption by the soil.

(Source: AS/NZS 1547:2012 Standards Australia)