Glossary of soil physical terms

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Introduction

This document is based on Soil Bureau Laboratory Report EP31, which was produced as guide to staff on soil-water terminology.

It addresses a need to avoid inconsistency in the use of these terms within Landcare Research.

Density

Particle density

Particle density is the mass per unit volume of primary soil particles (i.e. excluding all voids).

Abbreviation: ρ_p

Units: Mg/m^3 or t/m^3

Notes:

Specific gravity, often used as an equivalent, is not an acceptable term.

Dry bulk density

Dry bulk density is the dry mass per unit bulk volume of soil (i.e. including all voids).

Abbreviation: DBD or ρ_b

Units: Mg/m^3 or t/m^3

Notes:

Dry mass is the mass of a soil sample remaining after drying to consistent mass at 105°C (usually 16–24 hours drying). The term 'bulk density' alone is not sufficient, as both 'dry' and 'wet' bulk density may be measured. Hence a water-content qualifier needs to attached to the term.

Porosity

Total porosity

Total porosity is the proportion of a unit volume of soil not occupied by soil particles, i.e. the voids. These voids may be occupied by liquid or gas.

Abbreviation: TP

Units: dimensionless, often expressed as a percentage (%)

Notes:
Total porosity is derived from the two previous density terms, i.e. $TP = 1 - (\rho_b/\rho_p)$.

K_{-40} pores

K_{-40} pores is the proportion of soil volume drained between the pressure levels of 0 and –0.4 kPa on the soil-water desorption curve, i.e. pores >750 µm equivalent cylindrical diameter (ECD).

Units: dimensionless, often expressed as a percentage (%)

Notes:
The hydraulic conductivity of soil containing pores of >750 µm has been regarded as representing hydraulic conductivity associated with biologically generated cavities.

ECD is a term used to approximately characterise the irregularly shaped cross-sections of soil pores, by assuming pores are round and of uniform cross-section along their lengths. Using the capillary rise relationship, pores drained at a particular water potential may then be ascribed an average diameter.

Very large pores

Very large pores is the proportion of the soil volume drained between the pressure levels of 0 and –1 kPa on the soil-water desorption curve, i.e. pores >295 µm ECD.

Abbreviation: VLP

Units: dimensionless, often expressed as a percentage (%)

Notes:
The ECD of these pores corresponds to the root diameters of common, agronomically important plants.

Macroporosity

Macroporosity is the proportion of soil volume drained between the pressure levels of 0 and –5 kPa on the soil-water desorption curve, i.e. pores >60 μm ECD.

Abbreviation: MP

Units: dimensionless, often expressed as a percentage (%)

Notes:
The term 'large pores' is often used as an equivalent to macroporosity. Sometimes the term 'air capacity' has been equated to macroporosity, but air capacity has a different definition (see below). For a review of pore-size classification, see Luxmore (1981) and Hamblin (1981).

Air capacity

Air capacity is the proportion of the soil volume drained betwen the pressure levels of 0 and –10 kPa on the soil-water desorption curve (i.e. pores >30 μm ECD).

Abbreviation: ACP

Units: dimensionless, often expressed as a percentage (%)

Notes:
As –10 kPa is taken as the laboratory approximation of the upper limit of the pressure range for which soil-water movement is still significant, the pore volume that is drained between this pressure and saturation is the minimal level for air-filled pores in the soil during most time periods.

Equivalent terms are 'volume fraction of air' or 'air-filled porosity'. The Soil Survey of England and Wales has a term 'air capacity' which is defined as "having pressure limits of –0.4 and –5 kPa." The –0.4 kPa limit is used as field experience indicates that water conditions are rarely wetter than this, because air is trapped in soil pores. However, there are two problems with this definition —

(1) The –0.4 kPa lower limit is difficult to measure accurately and is not often determined, unlike the 0 kPa limit. Furthermore, it is not particularly relevant, since if air is present in these large pores, their volume should be added to the air-capacity term, and the 0 kPa lower limit is therefore still appropriate.

(2) The closest term to 'air capacity' should be macroporosity, and not ACP.

Summary of the relationship between pores, ECD, and water potential.

Pore identifier	Potential at which drained (kPa)	EDC (μm)
K_{-40} pores	–0.4	>750
Very large pores	–1.0	>295
Macropores	–5.0	>60
Air capacity pores	–10.0	>30

Soil water

Total water potential

Total water potential is the energy with which water is held in the soil per unit mass of water. It is often expressed in terms of the negative pressure required to remove water from the soil (–kPa).

Abbreviation: (ψ), TWP

Units: J/kg

Notes:
The generic term, total water potential (ψ), is the sum of a number of terms for forms of potential energy with which the water is held within the soil. These are —

Matric potential. This is equal to the potential energy due to the attraction of the solid matrix, and is equated to the absorption and capillary forces which hold water to soil particles.

Abbreviation: ψ_m

Gravitational potential. Potential energy of water due to gravity.

Abbreviation: ψ_g

Osmotic potential. Potential energy due to the presence of solutes in the soil.

Abbreviation: ψ_o

For visually assessing soil water in the field, to Milne et al. (1991; p. 42).

Water content

Water content is the amount of water removed from a soil sample by drying to constant mass (usually 16–24 hours drying) at 105°C.

Abbreviation: WC [if on a gravimetric (weight) basis]
θ [if on a volumetric basis]

Units: dimensionless, often expressed as a percentage (%)

Notes:
'Moisture content' is not an acceptable term.

Water desorption curve

Water desorption curve. The relationship between water content θ and matric potential ψ_m as determined by laboratory procedures on an undisturbed core.

Available-water capacity

Available-water capacity is the proportion of the soil volume drained between the pressure levels of –10 and –1500 kPa.

Abbreviation: AWC

Units: dimensionless, often expressed as a percentage (%).

Notes:
A distinction needs to be made here between available-water capacity and available water. Available-water capacity is the proportion of soil volume which is drained by appropriate pressure levels. It is a permanent feature of a soil's geometry; it is measured as a proportion or percentage and so is analogous to porosity. In comparison, the available water removed per unit soil volume has a physical reality after being summed over a depth range, either on a horizon or profile basis, and hence will have units of depth (e.g. millimetres).

The limits of AWC have been changed from what was once generally accepted; these were –20 and –1500 kPa, and many older analyses still quote these earlier limits. Often when the term 'available water' is used, AWC is in fact meant. The term 'moisture volume fraction' has been used as an equivalent, but as the word 'moisture' is no longer valid, the term is not now acceptable.

Readily available water capacity

Readily available water capacity is the proportion of the soil volume drained between the pressure levels of –10 and –100 kPa.

Abbreviation: RAWC

Units: dimensionless, often expressed as a percentage (%).

Notes:
The limits of RAWC have been changed from what was once generally accepted; these were –20 and –100 kPa, and many older analyses still quote these earlier limits.

Non-available water capacity

Non-available water capacity is the proportion of the potentially drainable soil volume left undrained at a pressure level of –1500 kPa.

Abbreviation: NAWC

Units: dimensionless, often expressed as a percentage (%).

Notes:
Included for the sake of completeness; water held in this pressure range is usually not available to plants.

Horizon available water

Horizon available water is the AWC for a soil horizon, multiplied by the horizon thickness in millimetres.

Abbreviation: HAW

Units: mm

Notes:
Since this is not an amount of water, the term 'capacity' is not used, and the unit of measurement is linear, i.e. horizon thickness. While the convention for profile and horizon descriptions is to quote depths in centimetres, for water-use purposes millimetres are preferred.

Horizon readily available water

Horizon readily available water is the RAWC for a soil horizon, multiplied by the horizon thickness in millimetres.

Abbreviation: HRAW

Units: mm

Profile available water

Profile available water is the summation of HAW over potential rooting depth.

Abbreviation: PAW

Units: mm

Notes:
The terms 'profile storage', 'storage' and 'total available water' are often used as synonyms for PAW. It has also been suggested that AWC should be equated to PAW, but this is likely to lead to confusion.

Profile readily available water

Profile readily available water is the summation of HRAW over potential rooting depth.

Abbreviation: PRAW

Units: mm

Actual rooting depth

Actual rooting depth is as measured in the field. It is specific to profile and crop.

Abbreviation: ARD

Units: mm

Notes:
In areas where shallow water tables occur, the ARD may vary seasonally.

Potential rooting depth

Potential rooting depth is the depth of soil that can provide a suitable medium for root development, retain water in desirable quantities, and supply nutrients. A number of estimations of potential rooting depth are available; these are (1) 1000 mm, (2) 760 mm, (3) depth to the first horizon limiting to root penetration.

Abbreviation: PRD

Units: mm

Notes:
Whether or not roots fully use the PRD depends on the species of the plant and its stage of development; see Griffiths (1985, p.5).

Field capacity

Field capacity is the water content θ that exists in a soil horizon or profile after gravitational drainage from a saturated condition falls to a rate that is insignificant (i.e. a flux of ≤1 mm/day).

Abbreviation: FC

Units: dimensionless, often expressed as a percentage (%)

Notes:
Field capacity is a popular term used to identify the upper limit of AWC. Strictly speaking the term is a misnomer, as 'capacity' should refer to a proportion of soil volume and FC to a point on the soil-water desorption curve. It is commonly equated to the laboratory-determined upper pressure boundary water content of the AWC, i.e. –10 kPa. It has been variously approximated over the years by –33, –20 and –10 kPa, but now should be restricted to field determinations. Some soils do not have a unique field capacity.

Permanent wilting point

Permanent wilting point is the water content θ at which most agronomically important plants permanently wilt. It is most commonly equated to the water content at the laboratory-determined lower pressure limit of AWC, i.e. –1500 kPa.

Abbreviation: PWP

Units: dimensionless, often expressed as a percentage (%)

Notes:
PWP is determined on samples taken at field-moist water content. PWP was originally defined as a gravimetric water content.

Profile extractable water

Profile extractable water is water stored in a soil profile between FC and an 'extreme lower water content limit' summed over the actual rooting depth.

Abbreviation: PEW

Units: mm

Notes:
The rationale behind this term is to emphasise the alternatives of determining plant-water availability in the field by distinguishing what are laboratory approximations from field determinations, i.e. the 'available' water terms from the 'extractable' terms. However, as yet the 'extreme lower water content limit' has not been defined. A possible definition is 'the lowest profile water content monitored in a season when moisture has been limiting and the crop has been under stress'. This limit would be crop specific. In agronomic publications, PEW is often referred to as plant-available water.

Horizon extractable water

Horizon extractable water is water stored in a soil horizon between FC and an 'extreme lower water content limit'.

Abbreviation: HEW

Units: mm

Profile readily extractable water

Profile readily extractable water is the water stored in the soil profile over the actual rooting depth between FC and a value where stomatal closure is induced or, in pasture, where dry-matter production starts to decline because soil water is limiting.

Abbreviation: PREW

Units: mm

Notes:
PREW is a field-derived equivalent of PRAW.

Horizon readily extractable water

Horizon readily extractable water is the water stored in the soil horizon between FC and a value where stomatal closure is induced or, in pasture, where dry-matter production starts to decline because soil water is limiting.

Abbreviation: HPREW

Units: mm

Notes:
HPREW is a field derived equivalent of HRAW.

Estimated profile available water

Estimated profile available water. In this estimation of water stored in the profile, AWC is used for the A horizon and RAWC for the remainder of the potential rooting depth.

Abbreviation: EPAW

Units: mm

Notes:
This definition may be suitable for shallow-rooting grasses, but is less appropriate for tree or vine crops, which may not have extensive, shallow root systems.

Soil-water deficit

Soil-water deficit is the amount of water by which evapotranspiration exceeds rainfall once PAW is exhausted, as computed on a daily balance.

Units: mm

Notes:
In soils with water tables in close proximity to ARD, upward fluxes of water to ARD may occur. Lateral flow may also occur as an input. However, the assumption behind the simpler calculation of a soil-water deficit is that of a profile with water input only from above.

Soil-water surplus

Soil-water surplus is the amount of water by which rainfall exceeds evapotranspiration once PAW is recharged, as computed on a daily balance.

Units: mm

Soil-water depletion

Soil-water depletion is the amount of water in a profile extracted by evapotranspiration from a recognised upper water-content limit, e.g. –10 kPa pressure level or FC.

Units: mm

Soil-water movement

Infiltration

Infiltration is the process by which water moves into the ground. The rate of infiltration varies with time. This rate tends towards a steady-state value over a period of time. This steady-state rate is a reproducible soil property and is largely independent of initial soil-water conditions.

Abbreviation: Q_i

Units: m/s

Hydraulic conductivity

Hydraulic conductivity is the ratio of soil-water flux to hydraulic gradient.

Abbreviation: K

Units: m/s

Saturated hydraulic conductivity is the hydraulic conductivity at a saturated water content where the hydraulic gradient can be taken as unity.

Abbreviation: K_s

Near-saturated hydraulic conductivity is the hydraulic conductivity at a near-saturated water content, e.g. at a θ value where pores >750 µm are non-conducting, i.e. at a matric potential of –0.4 kPa.

Abbreviation: K_{-40}

Unsaturated hydraulic conductivity is the hydraulic conductivity at an unsaturated water content.

Abbreviation: K_{us}

Hydraulic conductivity curve

Hydraulic conductivity curve is the relationship of hydraulic conductivity to volumetric water content.

Abbreviation: K curve

Sorptivity

Sorptivity is the gradient of short-term accumulated infiltration versus the square root of time.

Abbreviation: S

Units: ~~$m\sqrt{s}$~~ $m/\sqrt{s}$

Notes:

This is a measure of the amount of water absorbed by a soil between its initial volumetric water content and its final water content.

When plotted on linear versus square root time graph paper, sorptivity appears as a straight line, with an inflexion marking the transition to steady-state infiltration.

Diffusivity

Diffusivity is the hydraulic conductivity at a specific volumetric water content, divided by the gradient of the curve of pressure potential versus water content at that water content.

Abbreviation: D

Units: m^2/s

Notes:

Given θ, ψ, K and D, any three will solve the flow equation which is a combination of the conductivity and continuity equations. Diffusivity is a mathematical concept only, and has no strict physical reality.

Soil-water matric flux potential

Soil-water matric flux potential is a short-term absorption factor, being the integral of the diffusivity function over θ values from 0 to saturation.

Abbreviation: ϕ

Units: kPa

Permeability

Permeability is a general term to describe the ability of a soil horizon or profile to transmit water or air. It is a property of the soil, and is not dependent on the fluid involved.

Air permeability utilises the fact that gas flow through soil is little affected by the properties of the fluid. It can be measured at various water potentials, and characterises the air-filled conducting pore space.

Abbreviation: K_a

Units: m^2

Oxygen diffusion rate

Oxygen diffusion rate is the O_2 flux through the soil to a point at which it is consumed.

Abbreviation: ODR

Units: $kg\ m^{-2}\ s^{-1}$

Non-accepted terms

These terms may be encountered, but their use is not encouraged, or needs to be justified.

Drainage capacity is a term equated to ACP. It has also been defined as having pressure limits of –0.4 kPa and –10 kPa. The advisability of the –0.4 kPa limit, however, is questionable.

Easily available water capacity is the pore volume between –5 and –200 kPa.

Storage-pore capacity is the pore volume between 0 and –1500 kPa.

Water stress is a plant physiological term to describe the plant's response to inadequate water availability.

Rating systems

Information on rating systems was provided by Jim Watt, Noel Kendall, Maurice Gradwell and Peter Singleton (all NZ Soil Bureau, DSIR), Griffiths (1985) and Wilson & Giltrap (1984).

Dry bulk density

	Mg/m³ subsoil
Very high	>1.8
High	1.5–1.8
Moderate–high	1.3–1.5
Moderate	1.1–1.3
Moderate–low	0.9–1.1
Low	0.6–0.9
Very low	<0.6

Total porosity

	%
Very high	>75
High	65–75
Moderate–high	60–65
Moderate–low	45–50
Low	35–45
Very low	<35

Macroporosity

	%
Very large	>25
Large	20–25
Moderately large	15–20
Moderately small	10–15
Small	5–10
Very small	<5

Air capacity

	%
Non-limiting (to plant growth)	>10
Limiting	<10

Available-water capacity

These value are suitable for subsoils or profile average values, but are rather low for topsoils.

	%
Very high	>20
High	15–20
Moderate	10–15
Low	5–10
Very low	<5

Readily available water capacity

	%
High	>10
Moderate	5–10
Low	2–5
Very low	<2

Potential rooting depth

	metres
Very shallow	<0.2
Shallow	0.2–0.4
Moderately deep	0.4–0.8
Deep	0.8–1.2
Very deep	>1.2

Profile available water

Based on a potential rooting depth of 100 cm or actual rooting depth, whichever is the lesser.

Storage class	*mm of water*
Very high	>300
High	250–300
Moderate–high	200–250
Moderate	100–200
Moderate–low	50–100
Low	25–50
Very low	<25

Suitability for irrigation

Based on PAW (mm of water, based on potential rooting depth).

	Storage class	*mm of water*
Highly suitable	Very high	>130
Suitable	High	75–130
Moderately suitable	Moderate	50–75
Marginally suitable	Low	25–50
Unsuitable	Very low	<25

Profile readily available water

	millimetres
Very low	<25
Low	25–50
Medium	50–75
High	>75

Soil-water deficit

	millimetres
Minimal	<100
Slight	100–200
Moderate	200–300
Severe	300–400
Very severe	>400

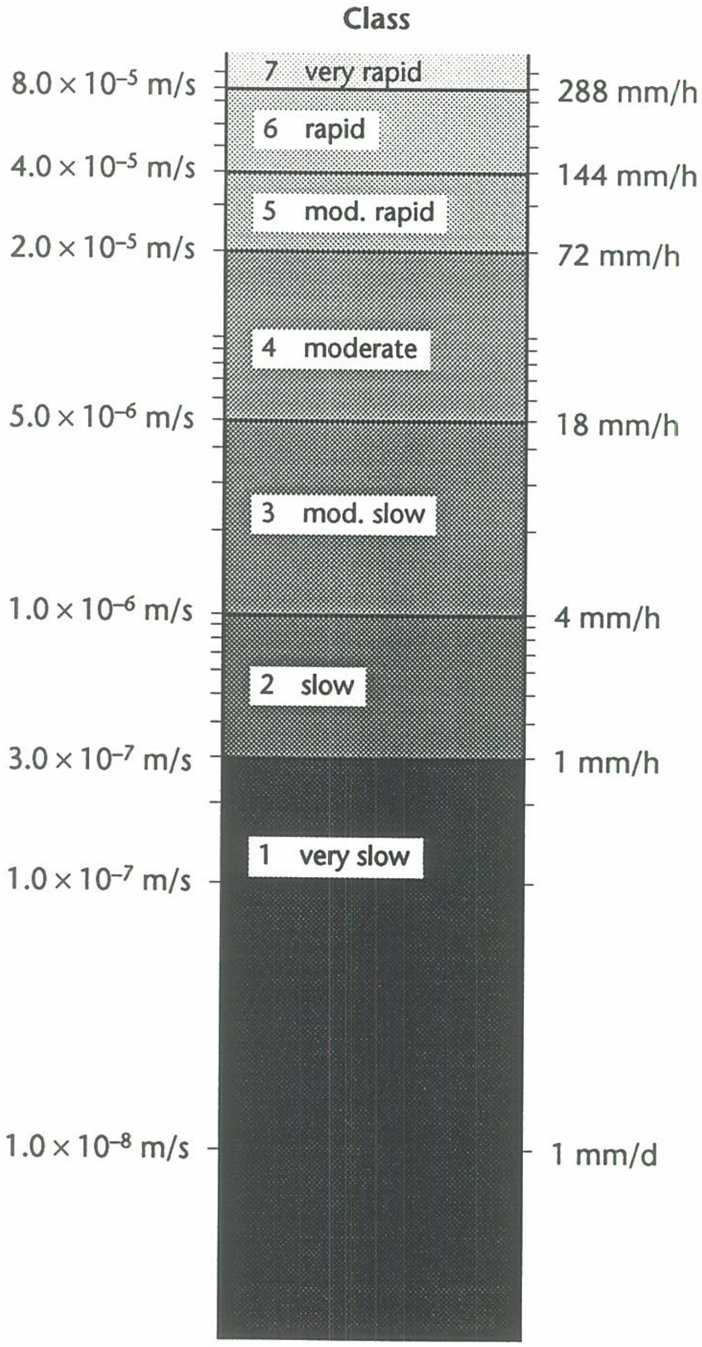
Air permeability

Limits for root growth are dependent on water potential; at more negative potentials a lower level of air permeability is acceptable.

	–1 kPa	*–10 kPa*
No limitation	4×10^{-11} m^2	4×10^{-11} m^2
Completely limiting	1×10^{-12} m^2	4×10^{-13} m^2

Permeability

Permeability classes from NZ Soil Bureau Soil and Water Assessement and Measurement Programme (SWAMP) 1983.



Multiply	mm/h	by	2.78×10^{-7}	to obtain	m/s
Multiply	m/s	by	3.60×10^{6}	to obtain	mm/h

References

GRIFFITHS, E. 1985: Interpretation of soil morphology for assessing moisture movement and storage. *NZ Soil Bureau scientific report 74.* 20 p.

HAMBLIN, A. 1985: The influences of soil structure on water movement, crop root growth and water uptake. *Advances in agronomy 38*: 95–152.

LUXMORE, R.J. 1981: Micro-, meso- and macroporosity of soil. *Soil Science Society of America journal 45*: 671–672 (and replies by Bouma, Beven and Skoop *Soil Science Society of America journal 45*: 1244–1246).

MILNE, J.D.G.; CLAYDEN, B.; SINGLETON, P.L.; WILSON, A.D. 1991: Soil description handbook. DSIR Land Resources. 133 p.

WILSON, A.D.; GILTRAP, D.J. 1984: Soil evaluation and classification system for orchard crop production. *NZ Soil Burea soil resources report SR6.*

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