2. ASSESSMENT OF LAND QUALITIES

This section describes how to assess 22 land qualities. It is difficult to develop a generic system for assessing land qualities which considers all variations in primary data. However, the scale of maps and the detail of associated field observations mean that more complex rules are difficult to justify. The assessment is expressly for establishing the best evaluation based on all available information.

As a general guide:

- Where a property is estimated e.g. soil water storage from texture and arrangement (see Appendix 1), soil depth and evidence of seasonal watertables, results should always be compared with any available measured values.
- Any derived map should be checked against field observations or other sources of complementary information such as DEMs, Landsat images or aerial photographs.

For example, if a map unit is rated as having low wind erosion hazard, but local knowledge strongly suggests that this is a common problem, the landscape position of the land unit might be incorrect or the underlying soil layer information might need adjustment, unless, of course, the higher than expected incidence was due to particularly poor management and not because the soils were inherently more susceptible.

Table 2. Land quality code values

Section	Description and code value	Sub-script	Acceptable codes (ratings)*
2.1	Ease of excavation (EXCAVA)	*x*	**H** (high), **M** (moderate), **L** (low), **VL** (very low)
2.2	Flood hazard (FLOODR)	*f*	**N** (nil), **L** (low), **M** (moderate), **H** (high)
2.3	Land instability (INSTAB)	*c*	**N** (nil), **VL** (very low), **L** (low), **M** (moderate), **H** (high)
2.4	Microbial purification (MI_PURE)	*p*	**VL** (very low), **L** (low), **M** (moderate), **H** (high)
2.5a 2.5b	pH at 0-10 (PH0_10), 20 (PH20) and 50-80 (PH5080) cm depth	*zf* *zg*	**Vsac** (very strongly acid), **Sac** (strongly acid), **Mac** (moderately acid), **Slac** (slightly acid), **N** (neutral), **Malk** (moderately alkaline), **Salk** (strongly alkaline)
2.6	Phosphorus export hazard (PHOS_L)	*n*	**L** (low), **M** (moderate), **H** (high), **VH** (very high) **E** (Extreme)
2.7	Rooting depth (URD)	*r*	**VS** (<15), **S** (<30), **MS** (30-50), **M** (50-80), **D** (>80), **VD** (>150) cm
2.8	Salinity hazard (SA_RIS)	*y*	**NR** (no hazard), **PR** (partial or low hazard), **MR** (moderate hazard), **HR** (high hazard), **PS** (saline land)
2.9	Salt spray exposure (SALTEX)	*zi*	**S** (susceptible), **N** (not susceptible)
2.10	Site drainage potential (SI_DRA)	*zh*	**R** (rapid), **W** (well), **MW** (moderately well), **M** (moderate), **P** (poor), **VP** (very poor)
2.11	Soil absorption (S_ABSOR)	*zj*	**H** (high), **M** (moderate), **L** (low), **VL** (very low)
2.12	Soil water storage (WA_STO)	*m*	**VL** (<35), **L** (35-70), **ML** (70-100), **M** (100-140), **H** (>140 mm/m for 0-100 cm **or** the rooting depth)
2.13	Soil workability (WORKAB)	*k*	**G** (good), **F** (fair), **P** (poor), **VP** (very poor)
2.14	Subsurface acidification susceptibility (SU_ACI)	*zd*	**L** (low), **M** (moderate), **H** (high), **P** (presently acid)
2.15	Subsurface compaction susceptibility (SU_COM)	*zc*	**L** (low), **M** (moderate), **H** (high)
2.16	Surface salinity (SALIN)	*ze*	**N** (nil), **S**, (slight), **M** (moderate), **H** (high), **E** (extreme)
2.17	Surface soil structure decline susceptibility (ST_DEG)	*zb*	**L** (low), **M** (moderate), **H** (high)
2.18	Trafficability (TRAFIC)	*zk*	**G** (good), **F** (fair), **P** (poor), **VP** (very poor)
2.19	Water erosion hazard (WA_ERO)	*e*	**VL** (Very low), **L** (low), **M** (moderate), **H** (high), **VH** (very high), **E** (extreme)
2.20	Water repellence susceptibility (WA_REP)	*za*	**N** (Nil), **L** (low), **M** (moderate), **H** (high)
2.21	Waterlogging/inundation risk (WA_LOG)	*i*	**N** (nil), **VL** (very low), **L** (low), **M** (moderate), **H** (high), **VH** (very high)
2.22	Wind erosion hazard (WI_ERO)	*w*	**L** (low), **M** (moderate), **H** (high), **VH** (very high), **E** (extreme)

* XX is the default NOT APPLICABLE value.

- Grey boxes indicate new land quality ratings in this edition.

2.1 Ease of excavation

This refers to the ease of excavating soil for building construction or earthworks, commonly from 30-150 cm deep. These earthworks relate to activities such as:

- levelling of building sites;
- installation of septic tanks and leach drains;
- shallow excavations for building foundations;
- deep ripping as preparation for tree crops, where soil preparation is deeper than normal cultivation depths (0-30 cm). For example, deep ripping may be used to break up subsoil pans or subsurface compaction layers (see land quality 3).

Table 2.1. Ease of excavation (adapted from Wells and King 1989)

Characteristic	Ease of excavation rating[1]			
	High (H)	Moderate (M)	Low (L)	Very low (VL)
Depth to rock (cm)[2]	Very deep (> 150 cm)	Deep (80-150 cm)	Moderately shallow to Moderate (30-80 cm)	Very shallow to Shallow (<30 cm)
Slope (%)[3] All soils except very deep sands	Flat to Moderate 1 (<15%)	Moderate 2 (15-30%)	Mixed (MX)	Steep (> 30%)
Very deep sands (>150 cm deep)	Flat to Gentle 2 (<10%)		Moderate 1 (10-15%)	Moderate 2 to Steep (>15%) and Mixed (MX)
Stone within profile (% volume)[4] (include cemented gravels)	Few to Common (<20%)	Many (20-50%)	Abundant (>50%)	-
Rock outcrop (% surface area)[5]	None (<2%)	Slight (2-10%)	Rocky to Very rocky (10-50%)	Rockland (>50%)
Waterlogging risk[6]	Nil to moderate	High	Very high	Very high[7]
Surface condition and soil texture	All coarse sand to clay loams, Non-hardsetting clays	Hardsetting clay or heavy clay	-	-
Soil texture and arrangement within top 100 cm	All coarse sand to clay loams, Moderate to well structured clays, Shrink-swell clays	Poorly structured clay or heavy clay layer present within top 100 cm	-	-

1 Rating determined by the most limiting characteristic.

2 See Appendix A1.2.

3 See Appendix A1.5. Very deep sands on slopes are treated separately because of the risk of pit/batter collapse.

4 See Appendix A1.6. 50 per cent by volume can be as much as 80 per cent by weight.

5 See Appendix A1.4

6 See Section 2.21

7 Swampy areas with watertables at <30 cm for most of the year.

2.2 Flood hazard

Flooding is the temporary covering of land by moving flood waters derived from overflowing streams and/or run-off from adjacent slopes.

Flooding should ideally be assessed using specific purpose flood studies, however in the absence of this information soil-landscapes within zones give a reasonable estimate. The table only assesses flood frequency, and not the intensity, which varies depending on catchment size, surface hydrology and rainfall.

Table 2.2. Assessment of flood hazard

	Flood hazard rating			
	Nil (N)	**Low (L)**	**Moderate (M)**	**High (H)**
Flood frequency return interval in years[1]	Nil	>10 (usually <100)	2-10	1
Geomorphic description/ landform	Flats above the flood limits and all other elevated areas.	Floodplains consisting of the high terraces of major rivers. Ill-defined drainage pathways associated with minor creeks and streams in low rainfall areas.	Well drained drainage depressions. Lower terraces of major rivers.	Stream channels, poorly drained drainage depressions and the immediate margins of major rivers.
Most likely landform[2] **units** High rainfall	FWD, FPD, etc.	FPW(s), SAL, SAS, SWM(s)	DDW	BCH, DDP(s), FPP(s), STC(s), WAT
Moderate rainfall	FWD, FPD, etc.	DDW, FPW(s), SAL, SAS, SWM(s)	DDP(s), FPP(s)	BCH, STC(s), WAT
Low rainfall	FWD, FPD, etc.	DDW, FPW(s), SAL, SAS, SWM(s), FPP(s)	DDP(s), STC(s)	WAT

[1] Refer to Water Authority flood studies (where available) which delineate land susceptibility to flooding and estimated flood frequency.

[2] See Table 1.5e.

2.3 Land instability hazard

Land instability assesses the potential for rapid movement of a large volume of soil. This includes mass soil movement through slope failure, shifting sand dunes, wave erosion and subsidence in karst topography (land underlain by caves).

Three factors are essential for landslips to occur (from Pilgrim and Conacher 1974):

- a threshold slope of 27 per cent;
- the presence of through-flow;
- a range of soil factors (that affect through-flow and shear strength).

Other factors that may need to be considered include:

- geological factors such as attitude of bedding planes relative to slope, rock fracture and shear zones, the nature of any clay minerals present in the weathered rock (and soil);
- topographic features such as proximity to cliff or scarp faces and the angle of repose of loose materials;
- climatic features such as the susceptibility to groundwater saturation of the regolith.

Table 2.3a is derived from slope instability hazard (Wells and King 1989) and land instability hazard (Tille and Lantzke 1990). It also considers karst topography, such as occurs on the limestone ridge of the Leeuwin-Naturaliste Coast where there are problems with subsidence and cave collapse (Tille and Lantzke 1990).

Table 2.3a. Assessment of land instability hazard

	Land instability rating				
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**
Site description	Gentle slopes <10%	Moderate slopes (10-27%) that shed water readily or where it is unlikely that significant seepage or through-flow will occur.	Moderate slopes (10-27%) where soil cover is relatively thin (<100 cm) and basement rock outcrop is common. Seepage or through-flow may occur. Steep (>27%) sand dunes where significant seepage or through-flow is unlikely.	Steep slopes (>27%), sloping valley headwaters and side slopes where significant seepage or through-flow is likely and/or colluvial material is deep. Areas underlain by caves.	Areas already subject to landslip or earth flows. Areas susceptible to wave erosion. Areas susceptible to sand dune movement (potential or actual). Areas known to be underlain by caves.

Alternatively, Tables 2.3b and 2.3c may be used to determine the land instability hazard of a land unit.

1. Using Table 2.3b, assign each land unit a score between 0 and 10 for each of the following factors: slope, soil depth, waterlogging risk and landform.
2. Add the scores together.
3. Determine the land instability hazard from the total instability score using Table 2.3c.

Table 2.3b. Determining land instability scores

	0	1	2	3	6	10
Slope[1]	Flat to gentle (<10%)	-	Moderate 1 (10-15%)	Moderate 2 (15-27%)	Steep (>27%)	-
Soil depth[2]	Very deep (>150 cm)	Deep (150-100 cm)	Very shallow to Moderate (<100 cm)	-	-	-
Waterlogging[3]	Nil (N)	Very low to Low (VL-L)	Moderate (M)	High to Very high (H-VH)	-	-
Landform[4]	All other landforms	-	-	-	-	BCH, BLO, FDH, LSP, STC

1 See Appendix A1.5.

2 See Appendix A1.2.

3 See Section 2.21.

4 See Table 1.5e.

Table 2.3c. Assessing land instability land instability score derived from Table 2.3b

	Land instability rating				
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**
Total score	<3	3-4	5-6	7-9	>9

2.4 Microbial purification

Microbial purification relates to the ability of soil used for septic effluent disposal to remove micro-organisms which may be detrimental to public health. It is essentially a measure of the permeability and aeration within a soil profile, which influences its ability to:

- remove undesirable micro-organisms from septic effluent;
- provide suitable conditions for the oxidation of some organic and inorganic compounds added to the soil as effluent.

This attribute will be influenced by the time of travel through the soil profile which in turn is related to the size and distribution of pore spaces and the depth to watertable or an impermeable layer. Important soil characteristics include permeability, depth, particle size and the clay and/or organic matter content.

Table 2.4. Microbial purification conditions (adapted from Wells 1987)

Permeability of most limiting layer (Saturated hydraulic conductivity)[1]	Microbial purification rating			
	Very low (VL)	Low (L)	Moderate (M)	High (H)
A. **Very slow to Slow** (<5 mm/h. Drainage time weeks to months**)** Includes shallow gravels, sands and loams and other soils overlying bedrock or impermeable pans, many clays and sandy and loamy duplexes with poorly structured subsoils[3]	<0.5 m to impermeable layer or watertable[3] or slope >30%[2]	>0.5 m to impermeable layer or watertable[3] or slope 15-30%[2]	-	-
B. **Moderately slow to Moderately rapid** (5-130 mm/h. Drainage time days**)** Includes most many Loamy earths, Sandy earths, Sandy and Loamy duplexes with well structured subsoils.	<0.5 m to impermeable layer or watertable[3]	0.5-1.5 m to impermeable layer or watertable[3] or slope >30%[2]	1.5-2 m to impermeable layer or watertable[3] or slope 15-30%[2]	>2 m to impermeable layer or watertable[3]
C1. **Rapid to Very rapid** (>130 mm/h. Drainage time hours) for all soils except Calcareous deep sands, Pale deep sands and Gravelly pale deep sands. Includes very deep Brown, Red and Yellow deep sands.	<0.8 m to impermeable layer or watertable[3]	0.8-2 m to impermeable layer or watertable[3]	>2 m to impermeable layer or watertable[3]	-
C2. **Rapid to Very rapid** for **Calcareous deep and shallow sands, Pale deep and shallow sands and Gravelly pale deep and shallow sands and Poor or gritty brown deep and shallow sands and poor or gritty yellow deep and shallow sands.**	<5 m to impermeable layer or watertable[3]	>5 m to impermeable layer or watertable[3]	-	-

1 See Appendix A1.3.

2 When these soils occur on steep slopes lateral seepage may intercept the surface and result in ineffective purification.

3 Depth to rock, poorly structured/massive clay or seasonal watertable if known (see A1.2 and A1.10).

2.5 pH

The pH of a soil measures its acidity or alkalinity. In acid soils pH is a useful surrogate for aluminum toxicity, while in alkaline soils high pH can indicate the presence of calcium carbonate, high sodicity or the presence of toxic compounds like sodium carbonate (for more information see Moore *et al.* 1998a, Scholz and Moore 1998).

The standard method for measuring pH in WA is 1:5 0.01M $CaCl_2$ (pH_{Ca}). However, in most land resource surveys it has been measured in a 1:5 soil:water suspension (pH_w). It is preferable to record actual data rather than derived data, therefore pH should be recorded according to the method used. The pH measured using different methods should not be compared directly for site investigations. For general land interpretation purposes, the relationship between pH_w and pH_{Ca} can be estimated by the equation:

$pH_{Ca} = 1.04\ pH_w - 1.28$ (Brennan *et al.* 1997).

The most widely available pH measurement is for the surface layer. However, the pH of the topsoil varies dramatically, and based on a comparison of map unit and soil profile data, estimated mean values for topsoil pH is commonly underestimated. Hence it is suggested that only an estimate of subsoil pH should be attempted. Even for subsoil the value can only be used as an indicator because pH varies dramatically with land use and minor soil variations.

Soil depth

The pH should be recorded for each soil group layer (see Section 1.6 and Figure 6). It is then reported at the following predefined depths:

- 0-10 cm (the surface layer);
- 20 cm (used for assessing subsoil acidity);
- 50-80 cm. If there is a layer boundary within this depth use the higher value (used for assessing subsoil alkalinity).

Table 2.5. General pH ratings for land interpretation

	Soil pH rating						
	Very strongly acid (Vsac)	Strongly acid (Sac)	Moderately acid (Mac)	Slightly acid (Slac)	Neutral (N)	Moderately alkaline (Malk)	Strongly alkaline (Salk)
pH_w	< 5.3	5.3-5.6	5.6-6.0	6.0-6.5	6.5-8.0	8.0-9.0	> 9.0
pH_{Ca}	< 4.2	4.2-4.5	4.5-5.0	5.0-5.5	5.5-7.0	7.0-8.0	> 8.0

2.6 Phosphorus export hazard

Eutrophication and corresponding algal blooms are a worldwide problem for waterways and bodies of water such as wetlands, lakes and estuaries. Nitrogen (N) and phosphorus (P) are both essential for plant growth. However, as N is more difficult to control and because some algae (e.g. nodularia) can utilise atmospheric N, P is commonly targeted as the limiting nutrient for algal growth.

Phosphorus export hazard refers to the likelihood that P (usually applied as fertiliser), moves from a given land unit to where it can contribute to eutrophication of surface water. The phosphorus can move either dissolved in water or attached to soil particles. This quality does not consider movement into deep groundwater, which is more commonly associated with nitrogen.

Phosphorus movement through the landscape is influenced by many factors. In addition to the soil and landform, many other factors such as catchment size, drainage density and/or proximity to drains, rainfall/run-off, climate and the presence or absence of vegetation affect movement and should be considered. (A large, but not exhaustive list is provided in Weaver and Summers 1998.)

Dominant factors in most situations include total water flow, time of travel and catchment size, hence water movement factors influence P export because when water moves rapidly contact time between soil particles and P is insufficient for sorption (Summers *et al.* in prep.).

Soil characteristics such as Phosphorus Retention Index (PRI) are of secondary importance because even at low PRI values P is rapidly bound (i.e. adsorbed and/or fixed) in the topsoil for most soil types. Where P is bound to the topsoil, water erosion becomes the main mechanism of export. P is also lost through wind erosion, but this is usually associated with declining soil fertility rather than with eutrophication.

PRI assumes greater importance in uniform sands, because if water moves rapidly, contact time between soil particles and P may be insufficient for sorption to occur. Hence uniform sands are assessed separately. Bleached or pale sandy soils are extensive in many coastal areas in WA.

Table 2.6 estimates the inherent susceptibility of a land unit to export phosphorus. The rating is decided by the most limiting factor. For land use planning or management, the issue is not really where P is lost but what and where detrimental impacts occur. It is not possible to determine this from land quality information alone.

Table 2.6. Assessing susceptibility of land units to phosphorus export from the most limiting factor

Soil property	Phosphorus export hazard rating				
	Low (L)	**Moderate (M)**	**High (H)**	**Very high (VH)**	**Extreme (E)**
Assess for all soils Water erosion hazard[1]	Low	Moderate	High	Very high	Extreme
Flood hazard[2]	Low	Moderate	Moderate (for highly erodible soils)	High	High (for highly erodible soils)
Landform[3]	All other areas	FOS(s), FPD(s), HSC, HSP(s)[4]	DDW, SWM(s)[4]	DDP(s), FPP(s)	STC
Assess for uniform sands or soil with Rapid to Very rapid profile permeability only **(X1)** Depth to highest seasonal watertable[5] for sands with low phosphorus retention index (PRI ≤2[6] at 0-150 cm). Subsoils are pale throughout (e.g. Munsell value/chroma 8/4, 7/2 or paler).		>5 m	2-5 m	1-2 m	<1 m
(X2) Depth to highest seasonal watertable[5] for sands with low phosphorus retention index (PRI 2-5[6] at 0-80 cm). Subsoils are pale throughout.	>5 m	2-5 m	1-2 m	<1 m	<0.5 m
(Y) Depth to highest seasonal watertable[5] for sands with moderate to high phosphorus retention index (PRI >5, 0-80 cm). Subsoil colour and textures increase with depth (e.g. Munsell value/chroma 8/6, 7/3 or darker).	>2 m	0.8-2 m	<0.8 m	<0.5 m	<0.2 m

1 See Table 2.19c.

2 See Table 2.2.

3 See Table 1.5e.

4 Swamps may be downgraded to low or moderate hazard where drainage from the swamp (e.g. saturation flows) are unlikely. Hillside seeps may be downgraded to low if they usually occur far from any drainage lines.

5 See Appendix A1.10.

6 Allen and Jeffery (1990) recommend a low value for phosphorus retention index of <5. This is supported by Summers *et al*. (1996) that indicates 30 per cent of phosphorus applied may be lost from soils with PRI = 4. PRI <5 is recommended as the cut off when considering intensive land use developments. A low value of PRI <2 is sometimes used as the cut off value for less intensive (agricultural) developments. See Appendix A1.12.

2.7 Physical crop rooting depth

Rooting depth is the depth to the layer within the soil where the growth and penetration of the majority of plant roots are restricted. This assessment of rooting depth considers the physical restrictions including the presence of watertables. It excludes chemical restrictions which can be detected using other land qualities. It is a general classification aimed at annual crops. The depth to a seasonal watertable (imperfectly or poorly drained areas) is particularly variable between seasons and soil types. The rooting depth is assumed to be at the lower depth of the seasonal watertable (saturated for less than three months), or any depth that restricts rooting, e.g. clay, pan or gravel.

This land quality appears to be of limited value for deep rooted perennial plants because there is an extremely wide variation in the depth of root growth between plant species and also in their tolerance of different soil physical conditions. There is very limited information about how the physical (and chemical) properties in the deeper subsoil or regolith layers are spatially distributed and the effect this has on rooting conditions.

Method: Each soil layer is assessed as to whether it meets all the non-limiting criteria (Table 2.7a). If one or more limiting properties are present then the rooting depth is where the restriction occurs. Note that many layers are not completely impenetrable, or the degree of penetration decreases with depth. For example, in a shallow sand with 40 cm of sand directly overlying granite the roots will be restricted at 40 cm giving an rooting depth of moderately shallow (MS). In contrast, in a duplex soil with 40 cm sand over sodic clay, significant root penetration may occur to a depth of 70 cm, resulting in moderate (M) rooting depth. It is always a good idea to look for evidence of root penetration and evidence of crop health to help confirm limiting criteria.

Table 2.7a. Assessment of limiting values for rooting depth

Soil property	When to assess	Non-limiting value	Limiting value
Depth to watertable (>3 months)[2]	All soils	Nil, low or very low risk of waterlogging.	Very high waterlogging is always limiting. For areas with moderate to high waterlogging, root growth is generally limited to the lower depth of the seasonal watertable (saturated for >3 months) or depth to the impermeable layer.
Clayey subsoils	Clay content >30% in subsoil (i.e. soil texture is CL, C, or HC)	Porous, earthy soils or moderate to strongly pedal subsoils with a granular, sub-angular blocky, polyhedral, angular blocky (<50 mm) structure.	Subsoils with a columnar or prismatic (>100 mm) subsoil and massive or weakly pedal subsoils that are not porous[3]. As a general guideline, assume that roots will penetrate 30 cm into these clays.
Pans and other hard layers	All layers	Weathered or fractured pans which roots can penetrate.	Presence of ferricrete and other cemented pans, saprolite or bedrock.
Coarse fragments (% volume)	All layers	<70%[4]	>70%[4]

1 See Table 2.5 as a guide. Strongly alkaline soils can often contain sodium carbonate or high levels of exchangeable sodium (high ESP).

2 See Table 2.21d as a guide to watertable depth.

3 In clays or duplex soils look for evidence of root penetration as roots may penetrate into the clay layer, below where the initial texture contrast is observed.

4 70% by volume may be up to 90% (or more) by weight.

Table 2.7b. Assessment of limiting values for rooting depth

	Rooting depth rating					
	Very shallow (VS)	**Shallow (S)**	**Moderately shallow (MS)**	**Moderate (M)**	**Deep (D)**	**Very deep (VD)**
Depth to root restricting layer	<15 cm	15-30 cm	30-50 cm	50-80 cm	80-150 cm	>150 cm

2.8 Salinity hazard

This refers to the hazard of the land being affected by salinity in the future. It considers the maximum extent of saline land likely to develop given present land uses, clearing patterns and management practices. It is an estimate of the extent of salinisation when the water balance reaches a new (post-clearing) equilibrium (see also Section 2.16). McFarlane *et al.* (2004) report an estimate of over 5.4 million hectares in the south-west of Western Australia that have the potential to be affected by salinity in the future.

An accurate estimate of salinity risk is difficult because watertable rise is affected by climate, land use (vegetation), soil-landforms, hydrology and geology. This also has to be compared with current salinity information.

Estimating the extent of rising watertables on valley floors or drainage depressions is reasonably accurate. However, estimating the future extent of saline seeps, where groundwater is forced to the surface by bedrock highs or in areas with dissected or variable depth regolith is more difficult. Hence the accuracy of assessing salinity hazard will vary depending on the land units being assessed.

A general estimate of salinity hazard can be made using Table 2.8a (for more information see Moore 1998b). Table 2.8b provides an indication of the likely salinity hazard for different landforms according to rainfall. Ideally salinity risk should be refined using additional information. (See Land Monitor on the internet at www.landmonitor.wa.gov.au/.)

Table 2.8a. General estimate of salinity hazard

Salinity hazard rating				
No hazard[1] (NR)	**Partial or low hazard[1] (PR)**	**Moderate hazard (MR)**	**High hazard (HR)**	**Presently saline (PS)**
High positions in the landscape such as upland deep lateritic residuals, elevated coastal dunes, etc. Salinity will not develop because of the elevated position, low watertables, high permeability and/or the low salt store in the regolith.	Areas with small variation in local relief and geology where rising watertables may not affect all the land area, or where rising watertables are not presently saline, and the salt store in the regolith is low. Examples include areas on the Swan Coastal Plain, where watertables are at equilibrium but there is seasonal variation, or variation due to management in salinity levels.	Moderate hazard from deeper saline groundwater with a rising trend. Often refers to land with rising watertables immediately adjacent to saline land but with slightly higher relief, or slightly better drainage. Examples include some low relief plains or the outer margins of valley floors.	Salinity already present in limited areas or high hazard from shallow saline groundwater that is close to the surface with a rising trend. Often refers to land with rising watertables immediately adjacent to saline land with similar relief. Examples include very low relief plains or valley floors.	All areas where salinity status is moderate, high or extreme[2] (ECe >400 mS/m). Includes land units with Saline wet soils and Salt lake soils.

1 No hazard or partial hazard areas can include smaller undulations or sandy rises on saline valley floors, stream channels, lower footslopes or where saline seeps occur (e.g. where groundwater is forced to the surface through high bedrock, mafic dykes and other variations in geology).

2 See Table 2.16 for surface salinity ratings.

Table 2.8b. General guidelines to salinity hazard of landforms in different rainfall zones

Landform qualifier	High rainfall areas	Moderate rainfall areas	Low rainfall areas
BCH, BLO, CDE, CLI, FDH, FDL, LRI, LSP, RCR, RIS, ROC, SL_1, SL_3, SL_5, SL_C, SL_L, SL10, SL15, SL30, SPL, FOW	No hazard	No hazard	No hazard
DDP, DDW, FOS, FPD, FPP, FPW, FWD, GID, HSP, SWL, SWM, STC	No hazard, unless surface soils have slight salinity (ECe >200 mS/m), then Partial or low hazard	Partial or low hazard	Partial or low hazard
FPWs, FWDs, GIDs	Moderate hazard	Moderate hazard	Moderate hazard
DDPs, FOSs, FPDs, FPPs, HSPs, STCs, SWMs	Moderate hazard	High hazard	High hazard
HSC, SAL, SAS	Presently saline	Presently saline	Presently saline

2.9 Salt spray exposure

This indicates exposure of land to salt spray drift from the ocean. The salt is carried in the wind and can harm plant growth and impact on the land capability for a range of agricultural uses. This land quality is relevant to coastal areas only. There are two ratings, N (none) and S (susceptible).

Table 2.9. Salt spray exposure

	Salt spray exposure rating	
	None (N)	**Susceptible (S)**
Degree of exposure to salt spray	Areas not exposed to regular ocean winds and salt spray	Areas exposed to regular ocean winds. Areas where salt spray is a recurring problem leading to regular plant damage only are included (landforms BCH, BLO, FDH, FDL).

2.10 Site drainage potential

For many developments it is important to have information about the relative drainage conditions of an area of land independent of the climate, which is referred to as *site drainage potential*. This is useful for land uses that require irrigation which may create waterlogging problems that would not occur naturally, or for developments which require drainage for existing problems. It is also generally related to assessment of salinity hazard (Section 2.8).

Site drainage potential provides an assessment of the suitability of the land for installing artificial drainage to remove excess water and reduce waterlogging and inundation. It is assessed independently of the current rainfall and waterlogging conditions.

The land qualities *site drainage potential* and *waterlogging/inundation* (Section 2.21) are related. In high rainfall areas in south-western Australia they are essentially the same, but in low rainfall areas can be different. For example, in low rainfall areas a soil with slowly permeable clayey subsoil may waterlog infrequently or for short periods only because of the low rainfall. However it would waterlog in a wet year, or if irrigated,.

Site drainage potential is influenced by:

- Internal drainage of the profile, which considers the *permeability* of the least permeable layer or the watertable depth. This may occur below the assessed soil profile (see Table 2.10a). It is also affected by the landscape position (Table 2.10b).

Permeability is an important property, especially when assessing land for irrigation potential. To minimise the risk of waterlogging and to ensure adequate leaching of salts from the profile, irrigated horticultural soils should have moderate or higher permeability. On the other hand, soils with rapid to very rapid permeability may result in excessive leaching of nutrients and be unable to supply adequate moisture to the crop without frequent irrigation. Hence rapid drainage is not always better.

- External drainage that is related to the landform pattern, i.e. slope and position in the landscape (see Table 2.10b).

Site drainage potential is assessed using an estimate based on Table 2.10a, or measured values where they are available. The assessment of permeability should be based on the hydraulic conductivity of the least permeable layer within the top 150 cm. This is regardless of whether or not it is a pedogenic soil horizon, an underlying substrate, or bedrock. This is then combined with consideration of landform (Table 2.10b) to obtain the final rating.

Table 2.10a. Permeability classes (adapted from O'Neil 1952)

Profile permeability class	Hydraulic conductivity[1] (mm/h)	Examples (general guide only)	Effect of impeding layer on internal drainage (general guide only)[2]
Very slow	<1	Duplex, gradational or clay soils with impermeable mottled and/or gleyed poorly structured clay soils and/or an extensive impermeable pan or bedrock.	Extensive impermeable layer. Water is removed very slowly through lateral movement and evaporation. Negligible percolation into deeper groundwater.
Slow	1-5	Duplex, gradational or clay soils with slowly permeable, poorly structured clays and/or a slightly permeable pan or bedrock.	Extensive impermeable layer. Water is removed slowly through lateral movement or evaporation. Minimal percolation into deeper groundwater.
Moderately slow	5-20	Duplex, gradational or moderately structured loams or clays, or soils where permeability is slightly increased by gravel or sand.	Impeding layer partially restricts water movement. Water is removed slowly. Main water movement is lateral. Minimal percolation into deeper groundwater.
Moderate	20-65	Duplex, gradational or well structured loams or clays, or soils where permeability is increased by a large amount of gravel or sand.	Impeding layer partially restricts water movement. Water is removed slowly. Main water movement is lateral, though some downward percolation is also likely.
Moderately rapid	65-130	Similar to above, but includes well structured loams, deep sandy gradational soils or deep sands over an impermeable layer at several metres.	No impermeable layer. Highly permeable soils mean that lateral water movement could still be effective in removing water. Main water movement is downward, though some lateral movement is also likely.
Rapid	130-250	Deep sands (e.g. sandplain with fine or medium sand and some clay at depth).	No effective impermeable layer. Minimal lateral water movement. Highly permeable soils mean that lateral water movement could still be effective in removing water. Main water movement is downward.
Very rapid	> 250	Deep coarse sands (e.g. sand dunes with minimal profile development).	No effective impermeable layer. Minimal lateral water movement.

1 Use the most restrictive layer in the soil profile.

2 Use as a general guide only. This is an attempt to assess how readily a soil would be drained if a significant amount of rainfall occurs. This is distinct to estimating local soil wetness conditions (e.g. McDonald *et al*. 1990), which identifies few soils in low rainfall areas.

Table 2.10b. **Guide for assessing site drainage potential based on landform and permeability (similar to Table 2.21b)**

Landform	Waterlogging/inundation risk rating in high rainfall districts					
	Nil (R)	**Very low (W)**	**Low (MW)**	**Moderate (M)**	**High (P)**	**Very high (VP)**
W. WAT	-	-	-	-	-	Very slow to Rapid
A. SAL, SWM, STC, DDP,	-	-	-	-	Very rapid	Very slow to Rapid
B1. FPD, FPP, SAS, GID	-	-	-	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow
B2. HSC, HSP				Moderate to Very rapid	Very slow to Moderately slow	
B3. FOS			Moderate to Very rapid	Very slow to Moderately slow		
C. BCH, CDE, FPW, FWD, SPL, SWL, LRI, DDW	-	Moderate to Very rapid	Very slow to Moderately slow		-	-
D. LSP, ROC, FOW	Rapid to Very rapid	Moderately slow to Moderately rapid	Very slow to Slow	-	-	-
E. SL_1, SL_L,	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow	-	-	-
F. RIS, SL_3, SL_C	Moderately slow to Very rapid	Very slow to Slow	-	-	-	-
G. BLO, CLI, FDH, FDL, RCR, SL_5, SL10, SL15, SL30	Very slow to Very rapid	-	-	-	-	-

1. The maximum waterlogging rating for all soils not in the wet soil groups (100-105, Table 1.5b) is moderate.
2. The minimum waterlogging rating for all in the wet soil groups (100-105, Table 1.5b) is moderate.

2.11 Soil absorption ability

Soil absorption is the ability of the soil to absorb a liquid. It is an important quality to consider in relation to the disposal of effluent, for example the disposal of waste water from septic tanks. Soil absorption is determined by the soil permeability, degree of waterlogging, soil depth and amount of stones in the soil. If the soil absorption ability at an effluent disposal site is inadequate there will be a high risk of surface ponding of water contaminated by microbes and a resultant risk to public health.

Table 2.11. Assessment of soil absorption ability by the most limiting factor (adapted from Wells and King 1989)

	Soil absorption rating			
	Very low (VL)	**Low (L)**	**Moderate (M)**	**High (H)**
Waterlogging/ inundation risk[1]	Very high	High	Moderate	Nil to low
Permeability class[2]	Slow to Very slow	Moderately slow	Moderate	Moderately rapid to Very rapid
Stones and boulders within profile[3] **(% volume)**[1]	-	Abundant (>50%)	Many (20-50%)	Very few to Common (<20%)
Depth of profile[4]	Shallow to Very shallow (<30 cm)	Moderately shallow (30-50 cm)	Moderate (50-80 cm)	Deep to Very deep (>80 cm)

1 See Section 2.21.

2 See Table A1.3a.

3 See Table A1.6. Note that 50% by volume can be as much as 80% by weight.

4 See Table A1.2.

2.12 Soil water storage

Soil water storage (SWS) is the amount of water that can be stored, available for plant water use. It is a major factor determining the yield potential in areas with a summer-dominant rainfall, such as the wheat growing areas of southern Queensland. In a Mediterranean environment where most rain falls during the growing season, soil water storage can be less important, depending on seasonal conditions. For example, in seasons where regular light showers ensure a water supply to the plant that closely matches crop transpiration, then differences between soils will be minimal. In other seasons, where the rainfall is abnormally high or low or unevenly distributed through the growing season then differences between soils will be evident. Soils with very low water storage capacity or unfavourable chemical or physical properties that restrict root growth invariably limit yields.

The large variation in the maximum rooting depth of different crops and the tolerance of plants to different soil conditions results in soil depth/plant rooting depth being the major variable affecting plant available water in many soils. Soil water storage should always be related to a specific crop or a depth interval e.g. 0-100 cm. This depth interval is appropriate for a general assessment for dryland annual crops.

Here the soil water storage is defined as the difference between upper storage limit (i.e. field capacity) and the lower storage limit (i.e. wilting point), summed over the upper 100 cm of the soil profile or the rooting depth, whichever is less. (Note: AWC - available water capacity or PAW – plant available water are simply the difference between field capacity and wilting point given in mm/m without the rooting depth restriction.)

If SWS is estimated from soil texture, then coarse fragments or gravel must be considered. As any water contained within coarse fragments is generally assumed to be unavailable to plants, the SWS is reduced proportionally for that layer according to the volume percentage.

The ironstone gravels common in the south-west of Western Australia can store significant amounts of water. Although anecdotal evidence would suggests that some of this water may be used by crops and pastures, this has not currently been quantified. Gravel is assumed to provide no water hence SWS of soils containing ironstone gravel may be underestimated.

In some soils with an inherently low AWC, the soil water storage may remain high due to the presence of high watertables. In some cases moisture in the capillary fringe above the watertable may remain available to plants throughout the summer months.

Method

1. Determine the rooting depth as shown in Section 2.7. If this is greater than 100 cm, use 100 cm as the rooting depth.
2. Use Tables 2.12b or 2.12c to estimate available water capacity in mm/m for each soil layer occurring within the rooting depth according to the texture and arrangement of that layer using the formula:
   layer AWC (mm) = layer thickness (m) x AWC (mm/m) x (100 – vol% coarse fragments)/100
   Note: Use measured values if available.
3. Sum the available water capacity for each soil layer to 100 cm or the rooting depth determined in step 1.
   AWC (mm) = depth (m) x AWC (mm/m) x (100 – vol% coarse fragments)/100
4. Use AWC (mm) value and Table 2.12a to assign the soil a soil water storage rating.
5. For soils with a rooting depth of 50 cm or more (see Table 2.7a) and a soil water storage rating of Very low to Moderate, increase the soil water storage rating if a permanent fresh watertable is present in the top 200 cm. Increase the rating to High if the minimum fresh watertable depth throughout the season is less than 150 cm, and to Moderate if the minimum fresh watertable depth throughout is between 150 and 200 cm.

Table 2.12a. Soil water storage

	Soil water storage rating				
	Very low (VL)	**Low (L)**	**Moderately low (ML)**	**Moderate (M)**	**High (H)**
Available water capacity of top 100 cm or to root restricting layer[1] (mm/m)	<35	35-70	70-100	100-140	>140

[1] See Tables 2.12b or 2.12c for guidelines.

Examples

1: A soil has 0.3 m medium sand over a well structured fine sandy loam to 1 m.
Soil water storage = (0.3 x 45 mm/m) + (0.7 x 195 mm/m) = 150 mm/m SWS which is classed as High.

2: A soil with 0.4 m medium sand with 40% gravel over an hardpan would normally be assessed to the rooting depth, e.g. 0.4 m x 45 mm/m x (100-40)/100 = 10.8 mm/m SWS, which is Very low.

Table 2.12b. Estimation of available water capacity (mm/m) using soil texture, sand size and structure (from Moore *et al.* 1998c)

Texture[1]	**Clay %**	**Sand size fraction**	**Available water capacity AWC[2] (mm/m) (References[3])**	
			Moderate to strong structure	**Weak structure or apedal**
Sands (KS, SS, S, FS)	<5	Coarse to Very coarse Medium to Coarse Medium Fine	- - - -	~20[a] 30-45[b] 40-50 50-70
Loamy sand/ Clayey sand (LS, CS)	5-10	Coarse Medium Fine	- - -	50-60[f] 60-90[f] 80-100[f]
Sandy loam (SL)	10-20	Coarse Medium Fine	110-220[l] 110-170[l] 170-220[l]	50-60[f] 60-100[c, d, f] ~140
Light sandy clay loam (L)	15-20	Coarse Medium Fine	120-150 170-220[l] ~180	50-60[e] 90-100[f] 100-120
Loam (L)	~25	-	150-240[h, l]	100-130[i]
Sandy clay loam (CL)	20-30	-	130-190[l]	100-130[g, i]
Clay loam (CL)	30-35	-	120-210[l]	~100
Sandy clay (C)	35-40	-	130-150[l]	80-100[f, i]
Clay (C)	>35	-	110-120[h, l]	90-140[h, i]
Self-mulching clay (C)	>35	-	~210[h]	-

[1] See Table A1.8.

[2] Soil water storage (SWS) may be reduced in proportion to the volume of gravels or stones within the profile, hence deep loamy gravels will have low or very low SWS.

[3] References:
a G. Luke (unpublished data)
b Hamblin *et al*. (1988)
c Hamblin and Hamblin (1985)
d Hamblin and Tennant (1981)
e S. McKeague (unpublished data)
f C. Henderson (unpublished data)
g M. Hegney (unpublished data)
h Williams (1983)
i Hollis and Jones (1987)

Table 2.12c. Estimated average available water capacity (mm/m) for varying soil textures and arrangements (from Table 2.12b)

Soil texture	Available water capacity (mm/m) for different soil arrangements						
	Loose (G)	Earthy or porous (E)	Poorly structured (P)	Moderately structured (M)	Strongly structured (S)	Shrink-swell (SW)	Pans and rock
Coarse sand (KS)	20	25	22	-	-	-	-
Light sand (SS)	30	45	40	-	-	-	-
Sand (S)	40	50	45	-	-	-	-
Fine sand (FS)	50	70	60	-	-	-	-
Loamy sand (LS)	60	90	75	-	-	-	-
Clayey sand (CS)	80	100	90	-	-	-	-
Sandy loam (SL)	90	110	80	120	150	-	-
Loam (L)	100	130	130	170	220	-	-
Sandy clay loam (SCL)	-	130	100	140	180	-	-
Clay loam (CL)	-	120	100	140	190	-	-
Clay (C)	-	110	90	130	200	130	-
Heavy clay (HC)	-	130	90	110	120	110	-
Fractured rock or pan (PF, RF)	-	-	-	-	-	-	10*
Weathered pan (PW)	-	-	-	-	-	-	10*
Weathered rock (PW)							10*
Solid rock or pan (PH, RH)							0

* Estimates for use in theoretical calculations as there is limited information for root water use in rock. If possible, derived values should be checked against real data.

2.13 Soil workability

This refers to the ease with which soil can be cultivated for cropping assuming the use of a tractor and plough and 10-15 cm depth of tillage. Machinery trafficability is included in this assessment as tractor access is normally required for cultivation. However machinery trafficability is also assessed as a separate land quality, as for many land uses vehicle access is important, even though cultivation may not be required. The rating is determined by the most limiting property of the land unit.

Table 2.13. Inherent limitations to soil workability (adapted from Wells and King 1989)

Soil property	Soil workability rating			
	Good (G)	**Fair (F)**	**Poor (P)**	**Very poor (VP)**
Waterlogging/inundation[1]: Where soil texture[2] in the top 15 cm is a coarse sand to sandy loam	Nil to moderate	High	Very high	
Where soil texture[2] in the top 15 cm is a loam to heavy clay	Nil to low	Moderate	High	Very high
Surface condition[3]	Loose, soft, firm, surface crust, saline or self-mulching. Hardsetting clayey or loamy sands	Cracking clays, Hardsetting sandy loams to clays		
Soil texture and arrangement within top 15 cm	All coarse sand to clay loams, Moderate to well structured clays, shrink-swell clays	Poorly structured clay or heavy clay layer present	-	-
Profile stones or boulders >200 mm (% volume)[4] (Include cemented gravels)	0-10%	10-20%	20-50%	>50%
Rock outcrop[5] (% surface area)	<2%	2-20%	20-50%	>50%
Depth to rock[6]	>30 cm	-	15-30 cm	<15 cm
Slope[7]	Flat to Gentle 2 (0-10%)	Moderate 1 (10-15%)	Moderate 2 (15-30%)	Steep (>30%)
Landform[8]	All others	DDP(s), DDW, GID(s), SL10	FDL, SL15	FDH, SL30, STC(s)

1 See Section 2.21.

2 See Table A1.8. Finer textured soils usually drain more slowly and are often workable over a narrow moisture range.

3 See Table A1.7.

4 See Table A1.6. 50% by volume may be 80% by weight.

5 See Table A1.4.

6 See Table A1.2.

7 See Table A1.5.

8 See Table 1.5e.

2.14 Subsurface acidification susceptibility

Subsurface acidification susceptibility is the hazard of the soil becoming acid below the cultivation layer (i.e. >10 cm below the surface) as a result of land management practices.

In WA, the major toxicity in acid soils is caused by aluminum (Al) as its solubility increases sharply when pH_{Ca} is less than 4.5 (or pH_w less than 5.6). However, Al is involved in reactions with organic matter (OM) to form non-toxic complexes, so toxicity tends to occur in the subsurface soil where OM concentrations are low. High concentrations of toxic Al reduce root elongation. A crop symptom is moisture stress due to the reduced root volume. Deficiencies of calcium, magnesium, molybdenum, nitrogen and phosphorus can also occur in acid soils.

In this manual, subsurface acidification susceptibility is assessed for the soil layer occurring directly below the normal depth of cultivation and below the surface horizon with maximum organic matter content (i.e. the horizon below the A1/AP horizon). The lower organic matter content in this layer increases its susceptibility and added lime typically only reaches this layer through leaching as it is below the cultivation depth. The layer assessed should be situated above the clayey subsoil where the plant roots are most active, and is usually found somewhere in the 10-70 cm depth range.

Susceptibility of the subsurface to acidification can be expressed in terms of the time taken before the subsurface acidifies to a critical pH where production losses are likely. Dolling *et al.* (2001) suggested the following formula to determine this time:

Time (years) = [(pH current - pH critical) x pH buffering capacity]/acid addition rate.

The assessment used in this manual assumes that the **pH critical** for the subsurface is pH_{Ca} 4.5 and pH_w 5.6. This is the case for cereal-lupin rotations, but not all crop-pasture rotations.

The **pH buffering capacity** (pHBC) of a soil is its ability to resist pH changes, either a pH decrease from an acid input (acidification) or an increase from the application of lime (lime requirement). Organic matter is the major factor, which influences pH buffering; clay content is the next important factor. The higher the organic matter or clay content the higher the soil's pHBC. Dolling *et al.* (2001) suggested the following formula to determine pHBC:

pHBC (t $CaCO_3$/ha.pH) = [0.955OC% + 0.011Clay%] x bulk density

In this formula, pHBC is expressed in terms of tonnes of lime per hectare to decrease acidity in a 10 cm thick layer by one pH unit. OC% is the percentage organic carbon content of the soil measured by the Walkley-Black method and Clay% is the percentage clay fraction of the soil. ***It should be noted that this formula is yet to be proven accurate for subsurface soils.***

The **acid addition rate** is the rate in which the soil acidifies as the result of a particular land use or farming system. It can be expressed in terms of the amount of lime (t/ha) required to neutralise the acidity produced by agriculture. Data presented by Dolling *et al.* (2001) show published mean acid addition rates **to the surface layer** for temperate slopes and plains from 0.025 to 0.080 t/ha/yr for continuous pastures (dryland lucerne) to 0.080 t/ha/yr for continuous cropping. The acidification rate to the subsoil will be lower, and will be influenced by the soil properties, management (i.e. cultivation practices) and the existing acidity in the topsoil. It is possible to calculate subsoil acidification that includes topsoil acidity estimates. However the actual relationship is unknown and topsoil pH estimates based on conventional soil-landscape maps are very unreliable. To simplify the equation a lower rate of subsoil acidification is assumed because the high pH bulge which is common below the surface soil indicates acidification occurs simultaneously. The calculations below use a mean rate of acidification to the **subsurface** that could be neutralised by 0.05 t/ha/yr of lime.

The land quality 'subsurface acidification susceptibility' is **only a general indicator** of soils with a high inherent risk of subsoil acidity because management, productivity and crop rotation all affect the rate of subsurface acidification and because pH values for land units are very variable (see Section 2.5). The specific crop or pasture species affects the critical pH; and some soils supply higher or lower concentrations of toxic Al at the same pH (e.g. peaty sands and grey sands have lower concentrations of extractable Al than most soils). The method for calculating subsurface acidification susceptibility is not appropriate for calcareous soils which have a low rating.

Method

1. Assess the pH buffering capacity of layer 2 of the soil (i.e. the horizon below the A1/AP and above the major texture increase in the top 80 cm, typically from 10 to 50 cm) using the formula:

   pHBC (t $CaCO_3$/ha.pH) = [0.955OC% + 0.011Clay%] x bulk density

   This formula presents the pHBC in terms of tonnes of lime per hectare to decrease acidity in a 10 cm thick layer by one pH unit (OC% is the organic carbon per cent and Clay% is the clay per cent).[14]

   If layer 2 lower depth is 20 cm or less, then pHBc is calculated for layer 3.

2. Using the pHBC values calculated above, the time in years for the soil layer to reach the critical pH_w of 5.6 under a cropping pasture rotation can be calculated using the following formula:

   Time (years) = [(pH_w-5.6) x pHBC] ÷ 0.05 (where 0.05 is the assumed subsoil acidification rate that could be neutralised by 0.05 t/ha of lime)

   If the current pH_w is 5.6 or less, the time in years will be 0 as the soil is already acid. Where pH_{Ca} values are available for the soil, the formula is altered to:

   Time (years) = [(pHca-4.5) x pHBC] ÷ 0.05

   If the **pH_w** is 8.5 or more, or **pH_{ca}** is 7.5 or more, the rate of acidification is automatically low (defaults to 100 years).

3. Estimate the rating from Table 2.14.

Table 2.14. Subsurface acidification susceptibility ratings (no extra lime applied)

Indicative time before subsurface soil reaches critical pH	Subsurface acidification susceptibility rating			
	Presently acid (P)	High (H)	Moderate (M)	Low (L)
Cropping/pasture rotation	0 years (pH_w currently <5.6)	<10 years	10-20 years	>20 years

[14] PHBC (cmol H+/t/pH) = pHBC (t $CaCO_3$/ha.pH) x bulk density/5.

2.15 Subsurface compaction susceptibility

Soil compaction describes the reduction in soil pore size and total pore space through applied stresses. The main cause on tilled soils is wheeled vehicular traffic, especially heavy dual-axle tractors[15]. The high strength of compacted soils restricts root elongation and results in a reduced soil volume available for water and nutrient uptake.

Traffic pans are common on many coarse-textured soils in the agricultural area of Western Australia. Ameliorating subsurface compaction through deep tillage improves yields.

Susceptibility to compaction relates to particle size distribution and the presence or absence of secondary structure and organic matter. Soils with a wide range of particle sizes, low organic matter and no secondary structure are particularly susceptible. If detailed particle size data is available the susceptibility to compaction should be determined using the *compaction index* developed by H. Daniel (Figure 4.2.2 in Needham *et al.* 1998b). Plough pans can also form under repeated cultivation, mostly in heavier textured soils, but are not dealt with in this land quality.

Table 2.15. Susceptibility of soils to subsurface compaction based on field texture, arrangement, coarse fragments and organic matter (adapted from Needham *et al*. 1998b)

Soil texture[1] (20-40 cm)	Subsurface compaction susceptibility rating		
	Low (L)	Moderate (M)	High (H)
Layers with >50% coarse fragments All textures	All (G, E, P, M, S, SW)	-	-
Layers with <2.0% OC Coarse sand to fine sand (KS, SS, S, FS)	-	All (G, E, P)	-
Loamy sand (LS)	-	Loose (G)	Earthy, Poorly structured (E, P)
Clayey sand (CS)	-	-	All (G, E, P)
Sandy loam (SL)	-	-	All (G, E, P, M, S)
Loam (L)	Moderately to Strongly structured (M, S)	Loose, Earthy, Poorly structured (G, E, P)	-
Sandy clay loam to clay loam (SCL)	Moderately to Strongly structured (M, S)	Earthy, Poorly structured (E, P)	-
Clay loam to heavy clay (C, HC)	All (E, P, M, S, SW)	-	-
Layers with >2.0% OC Coarse sand to fine sand (KS, SS, S, FS)	All (G, E, P)	-	-
Loamy sand (LS)	Loose (G)	Earthy, Poorly structured (E, P)	-
Clayey sand (CS)	-	All (G, E, P)	-
Sandy loam (SL)	-	All (G, E, P, M, S)	-
Loam (L)	All (G, E, P, M, S)	-	-
Sandy clay loam to clay loam (SCL, CL)	All (E, P, M, S)	-	-
Clay to heavy clay (C, HC)	All (E, P, M, S, SW)	-	-

1 See Table A1.9 for arrangement codes. It is assumed that the soil particles are well graded. If particles are narrowly graded (i.e. in the same size range) the rating should be reduced (e.g. from moderate to low).

15 Compaction by cattle is not considered as it tends to be restricted to the top 5 to 15cm of the soil (Greenwood and McKenzie 2001).

2.16 Surface salinity

Salinity refers to an excess of soluble salts in the soil solution in the top 30 cm, which adversely affects plant growth. The development of secondary salinity in WA is a result of a change in the water balance and rising watertables following the clearing of deep-rooted native vegetation and their replacement with shallow-rooted annual crops and pasture. It is most common in low-lying landscape positions such as valley floors.

It has been estimated that about one million hectares of the south-west of Western Australia are affected by salinity, with an annual increase of around 14,000 ha (McFarlane *et al*. 2004).

The land quality 'surface salinity' is intended to reflect, as far as is possible, current salinity status. The potential for the land to become saline in the future as the water balance comes to a new equilibrium is not considered. This is covered by the land quality 'salinity hazard' (Section 2.8). It should be noted that, as surface salinity is in a state of flux, estimates of this form of land degradation extracted from the map unit database may not be entirely current. Estimates of the extent of salinity will be influenced by the date when the map units were last attributed.

Table 2.16 presents guidelines for assessing the surface salinity. Where inductive electromagnetic salinity measurements are not available, a variety of indicators may be used. An approximate range in ECe (mS/m) is provided in Table 2.16, however due to large seasonal fluctuations measured soil samples may be misleading and should be compared with site observations, e.g. indicator plants or absence of sensitive species, to establish the salinity status of a land unit. (For more information see Moore 1998b.)

While the measurement of EC in a 1:5 soil:water (ECw) suspension is less reliable than the ECe, these data are more widely available and can be measured in the field. The figures presented were converted using the equation ***ECe = (364 X ECw)/SP mS/m*** where SP is the saturation percentage of the soil. The saturation percentage can be estimated as follows (see George and Wren 1985).

Soil texture	Saturation percentage (%w/w)
Sand to clayey sand	25
Sandy loam to sandy clay loam	32
Sandy clay to clay	45

It is important to remember that Table 2.16 is intended as a general guide only, and should be used to arrive at a best estimate of the degree of surface salinity.

Table 2.16. Assessment of surface salinity (0-30 cm)

	Surface salinity rating				
	Nil (N)	**Slight (S)**	**Moderate (M)**	**High (H)**	**Extreme (E)**
Approx. soil salinity range[1] (ECe mS/m)	<200	200-400	400-800	800-1,600	>1,600
Pasture salinity indicators[2]	Most agricultural pastures not affected.	Growth of sensitive species like yellow serradella, strand medic, rose and cupped clovers reduced	Clovers, medics and non-salt tolerant grasses reduced; patches of *H. marinum* (sea barley grass)	Patches of grassed and bare ground; *H. marinum* dominates, clovers and medics are usually absent	*H. marinum*, bare ground and halophytes such as samphire
Crop salinity indicators	Most agricultural crops not affected.	Very sensitive crops affected, e.g. lupins	Wheat affected, barley more tolerant. Cereals yield satisfactorily when seasonal conditions are favourable	Significant reductions in crop yields	Too saline for any crops
Approx. soil salinity range (EC 1:5 mS/m)	0-15 (sand) 0-20 (loam) 0-25 (clay)	15-25 (sand) 20-35 (loam) 25-50 (clay)	25-50 (sand) 35-70 (loam) 50-100 (clay)	50-100 (sand) 70-150 (loam) 100-200 (clay)	> 100 (sand) > 150 (loam) > 200 (clay)
Approx. EM38h reading[3] (ECa mS/m)	0-50	50-100	100-150	150-250	>250
Approx. watertable salinity[4] where ≤30 cm for >1 week (e.g. at least moderate waterlogging risk) **(EC mS/m)**	<100	100-500	500-2000	2000-4000	>4000

1 Use plant indicators as main guide. Soil salinity varies with seasonal conditions due to leaching by winter rains and capillary rise of salts over summer if the watertable is within 2 m of the surface. The degree of leaching is closely connected to the soil permeability and rainfall.

2 Salinity can vary dramatically with minor changes in topography, hydrology or geology, so record the most common condition.

3 This is the best method for assessing salinity is obtained by in situ measurements using inductive electromagnetic techniques. However this has not generally been done during soil-landscape surveys. Halve these values on deep sands, deep gravels, sandy earths and other profiles without a clayey subsoil by 80 cm.

4 Use as a general indicator only. There is no direct correlation between soil and groundwater salinity.

2.17 Surface soil structure decline susceptibility

This describes the susceptibility of soils to have their surface structure altered due to disturbance. A crusting or hardsetting soil surface is characteristic indication of structure decline within the top 15 cm. This results in reduced movement of water into and through the topsoil (and mechanical impedance for young plants).

The structure of many medium to fine-textured agricultural soils in WA has deteriorated in the relatively short period (50-80 years) since clearing for agriculture. A major reason for this decline has been excessive tillage, but heavy traffic and stock trampling also contribute. The soils have reduced infiltration, resulting in increased run-off. They are more compact requiring more tractor power, and can only be cultivated over a narrow moisture range. Seedling emergence is also adversely affected.

Surface soil structure decline occurs when physical stresses are applied to the soil, especially when the soil is wet. The wetting and drying cycle can significantly contribute to these stresses (especially when conditions approach saturation). Susceptibility of the soil depends on a complex interaction of a number of chemical and physical properties of the soil matrix and soil solution affecting the soil stability. Soils with a high exchangeable sodium percentage, low exchangeable calcium to magnesium ratio or dominated by kaolinitic clays are less stable. High organic carbon or salinity levels can increase stability. Coarse-grained sands with low clay content are not affected, but may compact (see Section 2.15). Soil solutions with low solute levels (e.g. rainwater) can encourage electrochemical instability, but increase of dissolved salts (e.g. in saline situations) can reduce electrochemical instability; the dissolved salts restrict dispersion of the clay fraction.

To assess surface soil structure decline susceptibility, first calculate the soil structural stability for all of the soil layers within the top 15 cm. This will include all of the soil which is likely be mixed and brought to the surface when cultivating the soil. Although most cultivation is to a depth of 10 cm only, 15 cm is used here to allow for some potential loss of topsoil or natural variation of depth to clayey subsoils in shallow duplex profiles.

Using Table 2.17a, assign each layer the appropriate score (between –5 and +5) for each of the following properties: organic carbon, ESP, electrical conductivity, Ca:Mg ratio, slaking, dispersion and surface condition or soil arrangement according to soil texture. Surface condition is used for the surface layer only; soil arrangement is used for any underlying layers. Add the scores together to determine the overall score for the layer. The surface soil structure decline susceptibility is then determined based on the layer in the top 15 cm with the lowest overall score using Table 2.17b.

Table 2.17a. Determining soil structure stability score (adapted from Needham *et al.* 1998a)

	Soil structure stability score								
	-5	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+5**
Organic Carbon%[1]				<0.8	0.8-1.5	1.5-2.5	>2.5		
Exchangeable sodium percentage[2]		>15	6-15		< 6				-
Electrical conductivity[2] **(ECe mS/m)**			<50	50-100		100- 150	>150		
Exchangeable Ca:Mg ratio[2]				<1	1-3	>3			-
Slaking[6]			C (Complete)	P (Partial)		N (Nil)			-
Dispersion[7]	C (Complete)	-	P (Partial)			N (Nil)			
Surface condition/*Soil arrangement*[3]: Coarse sand to Fine sand (KS, SS, S, FS)						Hardset or crust (H, C)/ *Poor (P)*	Saline (Z)	Firm (F)/ *Earthy (E)*	Loose or soft (S, L)/ *Loose (G)*
Loamy to clayey sand (LS, CS)			Hardset or crust (H, C)[4]/ *Poor (P)*[4]	Hardset or crust (H, C)[5]/ *Poor (P)*[5]		Firm (F)/ *Earthy (E)*	Saline (Z)	Loose or soft (S, L) *Loose (G)*	-
Sandy loam to Clay loam (SL, L, SCL, CL)		Hardset or crust (H, C)/ *Poor (P)*		Firm (F) *Earthy, strong, moderate (E, M, S)*	Soft, loose, (S, L)/ *Loose (G)*		Saline (Z)		-
Clay (C, HC)			Hardset (H)/ *Poor (P)*		Soft, firm (S, F) *Earthy, strong, moderate (E, M, S)*		Saline (Z)	Self-mulching, cracking (M, K)/ *Shrink-swell (SW)*	-

1 Organic carbon. Measured by the Walkley Black method, that is typically 20-25 per cent lower than the wet combustion methods (Rayment and Higginson 1992). See Table A1.11.

2 Only assess in soils with more than 10 per cent clay.

3 Assess surface condition (see Table A1.7) for surface layer only, assess soil arrangement (see Table A1.9) for other layers.

4 If fine sand content is high.

5 If fine sand content is low to moderate.

6 See Table A1.14.

7 See Table A1.13.

Table 2.17b. Assessing surface soil structure decline susceptibility for soil layers using the soil stability score from Table 2.17a

	Surface soil structure decline susceptibility rating		
	Low (L)	**Moderate (M)**	**High (H)**
Cumulative soil stability score	+1 to +15	-5 to 0	-6 to -15
Exclusions	Bare rock or very shallow soils (VSH, RST)		

Note: Soil structure decline does not apply to bare rock (soil group 201 – Table 1.5b). Additionally very shallow soils over rock, with a soil qualifier (Table 1.5c) of RST or VSH are automatically low.

Observations of the current field conditions under different management should be used to reinforce assessments based on limited chemical data. In general, field observations are useful, because susceptible soils are almost certain to show some decline. For more information on soil structure decline see Needham *et al.* (1998a).

2.18 Trafficability

Trafficability relates to the ease and safety of vehicle movement across the land surface. Vehicle access is important for many agricultural land uses. The use of tractors and other vehicles includes; cultivation, broadcasting fertilisers, spraying of pesticides or herbicides, mechanical harvesting and mustering livestock. Trafficability is considered separately from soil workability as there are a number of land uses which require vehicle access but do not require soil cultivation.

Table 2.18. Assessment of trafficability (adapted from Tille and Lantzke 1990)

	Trafficability rating			
	Good (G)	**Fair (F)**	**Poor (P)**	**Very poor (VP)**
Waterlogging/ inundation[1] for topsoil texture(<30 cm) [2]: Coarse sand to sandy loam	Nil to moderate	High	Very high	-
Loam to clay	Nil to low	Moderate	High	Very high
Rock outcrop[3] (% surface area)	None (< 2%)	Slight (2-10%)	Rocky to Very rocky (10-50%)	Rockland (>50%)
Slope[4] All soils except very deep sands	Flat to Gentle 2 (0-10%)	Moderate 1 (10-15%)	Moderate 2 (15-30%) and Mixed (MX)	Steep (>30%)
Very deep sands (>150 cm deep)	Flat to Gentle 1 (< 5%)	Gentle 2 (5-10%)	Moderate 1 (10-15%)	Moderate 2 to Steep (>15%) and Mixed (MX)
Landform[5]	FOS, FOW, SL_1, SL_3, SL_5	DDP(s), GID(s), SL10	BEA, BLO, FDL, LSP, SL15	CLI, FDH, SL30, STC(s), WAT

1 See Section 2.21.
2 See Table A1.8.
3 See Table A1.4.
4 See Table A1.5.
5 See Table 1.5e.

2.19 Water erosion hazard

Water erosion hazard is the inherent susceptibility of the land to the loss of soil as a result of water movement across the surface. It is a significant problem in WA affecting the long-term sustainability of agriculture in some areas and is a major source of water pollution including siltation and eutrophication, particularly in high rainfall areas. It is also an important cause of soil fertility decline as soil nutrients tend to be concentrated near the surface.

Water erosion is highly variable depending on seasonal and climatic factors with most soil loss occurring from a small proportion of the agricultural area. For example, a high rainfall event immediately after summer, when soil plant cover is low can result in a 'flush' of sediment and valuable topsoil nutrients into nearby drains. Management also affects erosion through the timing (and type) of cultivation, and frequency and intensity of waterlogging that affect saturation excess run-off.

The following general assessment is based on the *inherent erodibility* of a soil type (Tables 2.19a and 2.19b) and slope (Table 2.19c). As defined here water erosion hazard does not take into account land management practices (these are assessed in the land capability ratings tables). For more information see Coles and Moore (1998).

Method:

- Table 2.19a provides guidelines for assessing erodibility of individual soil layers (Figure 6). Assign a score for each characteristic, and add up the scores.
  If the total score exceeds 10, the soil layer can be considered **highly erodible**.
  If the total score is between 5 and 10, the layer can be considered **moderately erodible.**
  If the total score is lower than 5, the soil layer can be considered to have **low erodibility**.
- To calculate the soil profile erodibility score, add the erodibility score from all the subsurface layers within the top 80 cm. This will give you a soil profile erodibility score. Note: For slaking, dispersion and soil moisture ≤ 30 cm the erodibility rating is doubled because these properties near the surface have a large influence on water erosion.
- Gravel and stones protect the soil surface from erosion. If the surface layer contains more than 50 per cent coarse fragments, reduce the profile erodibility score by 5. If the surface layer contains more than 20-50 per cent coarse fragments, reduce the profile erodibility score by 2.
- Use Table 2.19b to convert the soil profile erodibility score into a soil profile erodibility class.
- Using Table 2.19c, estimate the water erosion hazard rating from the soil profile erodibility class and the landform position of the soil. Adjust the rating according the degree of waterlogging experienced by the land unit as instructed in the note below the table.

Table 2.19a. Soil layer erodibility scores

	Soil layer erodibility score			
	0	**1**	**2**	**3**
Organic carbon%[1]	>2.0	0.8-2.0	<0.8	-
Slaking[4] If soil layer depth ≤30 cm erodibility score * 2	N (Nil)	-	P (Partial)	C (Complete)
Dispersion[5] (Not applicable for sands – KS to CS) If soil layer depth ≤30 cm erodibility score * 2	N (Nil) XX (Not applicable)	-	P (Partial)	C (Complete)
Water repellence[6] (For sands – KS to CS. Layer 1 only)	N, L	M	H	
Soil structure or arrangement[2]**: coarse sand** (KS)	Earthy, Poor, Loose (E, P, G)	-	-	-
Light sand to clayey sand (SS, S, LS, CS)	-	Earthy, Poor (E, P)	Loose (G)	-
Sandy loam to clay loam (SL, L, SCL, CL)	-	Strong (S)	Earthy, Moderate (E, M)	Loose, Poor (G, P)
Clay (C, HC)	Shrink swell, Strong (SW, S)	Earthy, Moderate (E, M)	Poor (P)	-
Permeability of layers within or up to 30 cm below the layer being assessed[3]	Moderately rapid to Very rapid (MR, R, VR)	Moderate (M)	Moderately slow (MS)	Slow to Very slow (S, VS)
Soil moisture (year round) If soil layer depth ≤30 cm erodibility score * 2	Variable (V)	-	-	Wet, Partially wet (W, pw)

1 Organic carbon. Measured by the Walkley Black method, that is typically 20-25% lower than the wet combustion methods (Rayment and Higginson 1992). See Table A1.11.

2 See Table A1.9.

3 Low permeability (assume up to 30 cm) below the layer being assessed can affect lateral water movement in the soil layer. See Table A1.3.

4 See Table A1.14.

5 See Table A1.13.

6 See Table 2.20.

Table 2.19b. Soil profile erodibility classes

	Soil profile erodibility class		
	Low (i)	**Moderate (ii)**	**High (iii)**
Soil profile erodibility score	<15 Bare rock, water	15-30	>30

Table 2.19c. Susceptibility of land units to water erosion (based on soil erodibility and slope)

Landform[1]	Water erosion hazard rating					
	Very low (VL)	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**	**Extreme (E)**
A. Flats, Very gentle slopes, Crests (<3%) (FWD, FPD, SL_C, SL_1)	(1), (2)[2]	(3)[2]		-	-	-
B. Gentle slopes (3-5%), Long slopes, Footslopes, Floodplains (SL_3, SL_L, FOS, FOW, FPP, FPW)	(1)	(2)	(3)	-	-	-
C. Gentle slopes (5-10%), Well drained drainage depressions (SL_5, DDW)		(1)	(2)	(3)	-	-
D. Moderate slopes (10-15%), Poorly drained drainage depressions (SL_10, DDP)			(1)	(2)	(3)	-
E. Moderate slopes (15-30%), Stream channels (SL_15, STC)			-	(1)	(2)	(3)
F. Steep slopes (>30%) (SL30)			-	-	(1)	(2), (3)

NOTE: Waterlogging is High or Very high, increase rating by one column (e.g. from High to Very high).

1 See Table 1.5e.

2 Soil profile erodibility class – See Table 2.19b. Increase soil erodibility class for waterlogged soils.

2.20 Water repellence susceptibility

Water repellence susceptibility describes the risk of the soil becoming resistant to wetting, resulting in an uneven soil wetting pattern at the break of the season. In the paddock, patches of wet soil alternate with dry soil, which results in poor germination of crops and pasture. Water repellence may also contribute to increased water erosion due to reduced infiltration and increased run-off.

The susceptibility of a soil to water repellence is related to two main factors:

- Particle surface area. Soil materials with small surface area are more susceptible
- The supply of hydrophobic compounds which varies with the productivity of the system and land use.

Soil materials with a low surface area are more susceptible to water repellence. For example, the amount of hydrophobic material to completely coat a sandy soil would only cover a small proportion of a clayey soil (surface area of sands, 0.01-0.2 m^2/g, cf. clays 10-200 m^2/g). Most soils with clay content above 5% (0-10 cm) have low water repellence susceptibility. In general, the surface area is too large to be coated with hydrophobic organic compounds so the soils absorb water. However, a few soils with 10-20 per cent clay are water repellent under native vegetation. Water repellence is not induced on these soils by agriculture. Known examples include soils associated with the mallet hills in the Great Southern, the highly calcareous 'fluffy' or kopi soils in the Zone of Ancient Drainage and the blackbutt loams near Manjimup. Another exception are the calcareous sands on the coastal dunes, which are rarely coated with hydrophobic compounds, and even in swales where organic matter has built up, water repellence is usually only moderate.

The specific surface area can be inferred from particle size analysis or field texture for most agricultural soils (Table 2.20). In general, most sandy soils containing <5 per cent clay (0-10 cm) have some water repellence susceptibility.

Laboratory measures of water repellence are desirable for consistency. The main tests include:

- molarity of ethanol droplet test or MED (King 1981);
- water droplet penetration time or WDPT (Letey 1969)[16];
- angle of contact test or AC (Emerson and Bond 1963).

There are not many MED test results available for WA soils. The original work by King (1981) alerted users to large variation in test results due to soil temperature and soil moisture, which makes MED and WDPT unreliable in the field. A more recent paper by Doerr *et al*. (2002) indicates that high relative humidity[17] can increase the water repellence considerably. They concluded that comparisons between laboratory measures should be treated with caution if antecedent relative humidity prior to testing has not been recorded. They suggested that samples should be exposed to a period of high relative humidity before testing to best reflect critical field conditions. Table 2.20b indicates an approximate relationship between field derived water repellence measures and laboratory measures.

[16] Only applicable for slightly water repellent soils which cannot be distinguished by the MED test.

[17] As can occur just before rainfall.

Table 2.20a. Susceptibility of soils to water repellence (adapted from Moore and Blackwell 1998)

Surface texture[1]	Nominal Specific Surface area	Water repellence susceptibility rating			
		Nil (N)	**Low (L)**	**Moderate (M)**	**High (H)**
Sand (<2% clay) Light sand (SS)	**<0.1 m^2/g**	Coarse calcareous sands with very low amounts of organic matter[3]		Coarse to medium calcareous sands with moderate amounts of organic matter[3]	Pale grey sands (including coloured sands with a bleached surface layer)
Sand to weak clayey sand (2-5% clay) sand, fine sand (S, FS)	**0.1-0.5 m^2/g**		Some coloured sands and texture contrast soils with variable %clay (2-5%)	Coloured sands and texture contrast soils with a pale sandy surface and clay commonly only 2% (e.g. Esperance sandplain)[2]	-
Loamy sand or finer (>5% clay) loamy sand to clay (LS, CS, SL, L, CL, C)	**>0.5 m^2/g**	Most soils	Some soils with lighter surface textures (e.g. texture contrast soils) with 5-10% clay	-	Soils which are water repellent before clearing (e.g. soils associated with certain vegetation such as mallet)

1 See Table A1.8.

2 Moderate risk soils still require furrow sowing and press wheels to mitigate repellence effects.

3 See Table A1.11.

Table 2.20b. Relationship between field derived water repellence measures and laboratory measures (adapted from King 1981)

For soils tested at 20°C	Water repellence susceptibility rating			
	Nil (N)	**Low (L)**	**Moderate (M)**	**High (H)**
MED values (Molarity of ethanol which penetrates in 10 seconds)	Not applicable	<1	1-2	>2
Contact angle (between water drop and soil surface - degrees)	<75	75-86	87-92	>92
WDPT (seconds to penetrate)	<1	1-53	>53	Not applicable

2.21 Waterlogging/inundation risk

W*aterlogging* is excess water, in terms of saturated soil layers, in the root zone accompanied by anaerobic conditions. In saturated soils biological activity rapidly uses the available oxygen, retarding oxygen and water uptake and restricting root and plant growth. Waterlogging for extended periods near the surface (e.g. <30 cm) can result in poor crops or plant death. The ability to tolerate different periods of waterlogging varies greatly between crops. Also in many situations, the presence of a saturated layer or watertable deeper in the soil can be advantageous because a water supply is available to the plant and adequate air is available in the topsoil to maintain root activity.

Inundation is water ponding on the soil surface. The effect on plant growth can be severe if plants are growing actively because all soil oxygen available to plant roots is rapidly depleted by biological activity.

In the agricultural areas of WA, waterlogging is widespread and a major factor reducing crop and pasture yields, especially in wet years. Its magnitude is difficult to measure given the large variation between seasons and the incidence is probably under-estimated because perched watertables can go unnoticed unless the soil profile is examined in winter.

The term *drainage* is used by McDonald *et al.* (1990) to summarise local soil wetness conditions, and is comparable to the waterlogging/inundation classes described in Table 2.21d.

Tables 2.21a to 2.21c present guidelines for estimating waterlogging/inundation risk rating in different rainfall districts (Table 1.6c and Figure 5) using landscape position and soil permeability. The assessment is based on the duration of waterlogging during the growing season and ***assumes average seasonal rainfall***. Generally surficial watertables rise rapidly following the break of season (usually between April and June) and reach a maximum at the end of winter or during spring. Watertables can fall rapidly on sloping sites when the rains end. Perched watertables can also dry up rapidly. Watertables in flat, low lying landscapes tend to fall more gradually, and are often declining right up to the break of season.

Table 2.21d is the old method for estimating waterlogging/inundation risk. It is useful as a guide for the expected depth and duration of seasonal watertables. The reason Table 2.21d is no longer used to assess waterlogging/inundation risk is because in most cases there will be very little hard data for the assessment, and the surveyor will have to rely on experience and judgement. The use of indications in the soil profile such as the presence of mottled or gleyed layers is important, as is the presence of waterlogging indicator species, however, it will often be difficult to separate the effects of waterlogging and salinity.

Another reason Table 2.21d is no longer used is because the duration of waterlogging at different depths in the profile will vary considerably from the figures shown here in many situations.

Table 2.21a. Estimating waterlogging/inundation risk rating in high rainfall districts (>600 mm, Table 1.6c) from landform and soil permeability

Landform	Waterlogging/inundation risk rating in high rainfall districts					
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**
W. WAT	-	-	-	-	-	Very slow to Rapid
A. SAL, SWM, STC, DDP	-	-	-	-	Very rapid	Very slow to Rapid
B1. FPD, FPP, SAS, GID	-	-	-	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow
B2. HSC, HSP				Moderate to Very rapid	Very slow to Moderately slow	
B3. FOS			Moderate to Very rapid	Very slow to Moderately slow		
C. BCH, CDE, FPW, FWD, SPL, SWL, LRI, DDW	-	Moderate to Very rapid	Very slow to Moderately slow		-	-
D. LSP, ROC, FOW	Rapid to Very rapid	Moderately slow to Moderately rapid	Very slow to Slow	-	-	-
E. SL_1, SL_L,	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow	-	-	-
F. RIS, SL_3, SL_C	Moderately slow to Very rapid	Very slow to Slow	-	-	-	-
G. BLO, CLI, FDH, FDL, RCR, SL_5, SL10, SL15, SL30	Very slow to Very rapid	-	-	-	-	-

NOTE: 1. The maximum waterlogging rating for all soils not in the wet soil groups (100-105, Table 1.5b) is moderate.

2. The minimum waterlogging rating for all soils in the wet soil groups (100-105, Table 1.5b) is moderate.

Table 2.21b. Estimating waterlogging/inundation risk rating in medium rainfall districts (350-600 mm, Table 1.6c) from landform and soil permeability

Landform	Waterlogging/inundation risk rating in moderate rainfall districts					
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**
W. WAT	-	-	-	-	-	Very slow to Rapid
A. SAL, SWM, STC, DDP,	-	-	-		Rapid to very rapid	Very slow to Moderately rapid
B1. FPD(s), FPP(s), SAS	-	-	-	Moderate to Very rapid	Slow to Moderately slow	Very slow
B2. HSC, HSP(s)				Moderately slow to Very rapid	Very low to Slow	-
B3. FOS			Moderately slow to Very rapid	Very slow to Slow		
C. BCH, CDE, FPW(s), FWD(s), GID(s), SPL, SWL, LRI, DDW	Rapid to Very rapid	Moderate to Moderately rapid	Very slow to Moderately slow	-	-	-
D. LSP, ROC, FOW	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow	-	-	-
E. SL_1, SL_L,	Moderately slow to Very rapid	Very slow to Slow	-	-	-	-
F. RIS, SL_3, SL_C	Very slow to Very rapid	-	-	-	-	-
G. BLO, CLI, FDH, FDL, RCR, SL_5, SL10, SL15, SL30	Very slow to Very rapid	-	-	-	-	-

NOTE:
1. The maximum waterlogging rating for all soils not in the wet soil groups (100-105, Table 1.5b) is moderate.
2. The minimum waterlogging rating for all in the wet soil groups (100-105, Table 1.5b) is moderate.

Table 2.21c. Estimating waterlogging/inundation risk rating in low rainfall districts (<350 mm, Table 1.6c) from landform and soil permeability

Landform	Waterlogging/inundation risk rating in low rainfall districts					
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**
W. WAT	-	-	-	-	-	Very slow to Rapid
A. SAL, SWM, STC, DDP	-	-	-	Very rapid	Moderately rapid to Rapid	Very slow to Moderate
B1. FPD(s), FPP(s), SAS	-	-	Very rapid	Moderately slow to Rapid	Very slow to Slow	-
B2. HSC, HSP(s)			Rapid to Very rapid	Very slow to Moderately rapid		
B3. FOS		Very rapid	Slow to Rapid	Very slow		
C. BCH, CDE, FPW(s), FWD(s), GID(s), SPL, SWL, LRI, DDW	Moderately rapid to Very rapid	Moderately slow to Moderate	Very slow to Slow		-	-
D. LSP, ROC, FOW	Moderately slow to Very rapid	Very slow to Slow		-	-	-
E. SL_1, SL_L,	Very slow to Very rapid		-	-	-	-
F. RIS, SL_3, SL_C	Very slow to Very rapid	-	-	-	-	-
G. BLO, CLI, FDH, FDL, RCR, SL_5, SL10, SL15, SL30	Very slow to Very rapid	-	-	-	-	-

NOTE: 1. The maximum waterlogging rating for all soils not in the wet soil groups (100-105, Table 1.5b) is moderate.

2. The minimum waterlogging rating for all in the wet soil groups (100-105, Table 1.5b) is moderate.

Table 2.21d. Generic description of waterlogging classes in relation to duration of waterlogging and inundation and watertable depth (adapted from Moore and McFarlane 1998)

	Waterlogging/inundation risk rating					
	Nil (N)	**Very low (VL)**	**Low (L)**	**Moderate (M)**	**High (H)**	**Very high (VH)**
Inundation[2]	Never	< 1 day	< 4 days	< 2 weeks	< 2 months	> 2 months
Watertable ≤30 cm[2]	Never	< 3 days	1-7 days	1-8 weeks	2-3 months	> 3 months
Watertable ≤50 cm[2]	Never	< 1 week	1-4 weeks	1-3 months	3-6 months	> 6 months
Watertable ≤80 cm[2]	Never	1-4 weeks	1-3 months	3-5 months	> 5 months	Most of year
Pasture and crop indicators[3]	Healthy crops and pastures	Healthy crops and pastures	Reduced growth of lupins, lucerne	Reduced growth of wheat, canola	Very poor crop growth, root pruning of pastures	Annual pastures die, some perennials (e.g. kikuyu) are OK

1 Watertable sitting above ground surface.

2 Use data generated using Table A1.10 as a guide.

3 Assume that watertable is not saline.

2.22 Wind erosion hazard

Wind erosion hazard is the inherent susceptibility of the land to the loss of soil as a result of wind movement across the surface. Wind erosion has many adverse effects: sandblasting damage to crops, loss of macro- and micro-nutrients, long-term loss of productivity, and atmospheric pollution. There are also off-site costs to both individuals and the community. The dust lost from paddocks is rich in nutrients and is carried high into the atmosphere before being deposited, possibly thousands of kilometres downwind.

All soils are subject to wind erosion given certain conditions. The key is the level of disturbance by mechanical or animal action required to bring a soil to an erodible condition.

The *susceptibility of a soil* can be assessed from a simple matrix of surface texture and surface condition (Table 2.22a). The five categories of wind erosion hazard relate to the level of disturbance needed to bring the soil to a loose and consequently erodible condition. Soils in category (v) are highly susceptible because they have a loose surface and control must rely on the use of windbreaks and/or maintenance of adequate vegetative cover. Categories (iv) to (i) have decreasing susceptibility. They are less fragile and require some disturbance by machinery or stock to loosen the soil. Gravel both physically protects the surface and increases roughness and this reduces the wind velocity at the soil surface. The surface condition should be assessed when the soil is dry.

To use the tables, first determine the percentage of coarse fragments present on the surface. If there are less than 20 per cent coarse fragments, use Table 2.22a, if 20-50 per cent use Table 2.22b and if more than 50 per cent use Table 2.22c. The *susceptibility of a land unit* to wind erosion is assessed by combining soil susceptibility (Tables 2.22a, b or c) with landform (Table 2.22d). Landform and location influence wind speed and exposure to high winds. As defined here wind erosion hazard does not take into account land management practices (these are assessed in the land capability ratings tables).

Table 2.22a. Assessing susceptibility of bare soil to wind erosion from surface texture and surface condition for soils with <20% surface coarse fragments (adapted from Moore *et al.* 1998b)

Loose (L)[1]	Soft, Surface flake (S, X)[1]	Firm, Crusting, Cracking, Saline (F, C, K, Z)[1]	Hardsetting (H)[1]	Self-mulching (M)[1]	Wind erodibility rating
-	-		Coarse sand and sandy loam to clay[2] (KS, SL, L, SCL, CL, C)	Clay[3]	**(1)**
-	-	Coarse sand and sandy loam to Clay (KS, SL, L, SCL, CL, C)	-	Clay[3]	**(2)**
-	Coarse sand and sandy loam to clay (KS, SL, L, SCL, CL, C)	Light sand to clayey sand (SS, S, FS, LS, CS)	Loamy sand to clayey sand (LS, CS)	**Clay[3]**	**(3)**
Coarse sand (KS)	Light sand to clayey sand (KS, SS, S, FS, LS, CS)	-	-	Clay[3]	**(4)**
Light sand to clay (SS, S, FS, LS, CS, SL, L, SCL, CL, C)	-	-	-		**(5)**

1 Surface condition – see Table A1.7.

2 Surface texture – see Table A1.8.

3 Erodibility of self-mulching clays depends on the size of the particles created when clay mulches. The default value for self-mulching clays is (3).

Table 2.22b. Assessing the susceptibility of bare soil to wind erosion from surface texture and surface condition for soils with 20-50% surface coarse fragments

Loose (L)[1]	Soft, Surface flake (S, X)[1]	Firm, Crusting, Cracking, Saline (F, C, K, Z)[1]	Hardsetting (H)[1]	Self-mulching (M)[1]	Wind erodibility rating
-	-	Sandy loam to clay (SL, L, SCL, CL, C)	Sandy loam to clay[2] (SL, L, SCL, CL, C)	Clay[3]	**(1)**
-	Sandy loam to clay (SL, L, SCL, CL, C)	Coarse sand to clayey sand (KS, SS, S, FS, LS, CS)	Loamy sand to clayey sand (LS, CS)	**Clay[3]**	**(2)**
-	Coarse sand to clayey sand (KS, SS, S, LS, CS)	-	-	Clay[3]	**(3)**
Coarse sand to clay (KS, SS, S, FS, LS, CS, SL, L, SCL, CL, C)	-	-	-		**(4)**

1 Surface condition – see Table A1.7.

2 Surface texture – see Table A1.8.

3 Erodibility of self-mulching clays depends on the size of the particles created when clay mulches. The default value for self-mulching clays is (2).

Table 2.22c. Assessing susceptibility of bare soil to wind erosion from surface texture and surface condition for soils with >50% surface coarse fragments

Loose (L)[1]	Soft, Surface flake (S, X)[1]	Firm, Crusting, Cracking, Saline (F, C, K, Z)[1]	Hardsetting (H)[1]	Self-mulching (M)[1]	Wind erodibility rating
-	Sandy loam to clay (SL, L, SCL, CL, C)	Coarse sand to clay (KS, SS, S, LS, FS, CS, SL, L, SCL, CL, C)	Loamy sand to clay[2] (LS, CS, SL, L, CL, SCL, C)	Clay[3]	**(1)**
-	Coarse sand to clayey sand (KS, SS, S, FS, LS, CS)			**Clay[3]**	**(2)**
Coarse sand to clay (KS, SS, S, FS, LS, CS, SL, L, SCL, CL, C)	-	-	-		**(3)**

1 Surface condition – see Table A1.7.

2 Surface texture – see Table A1.8.

3 Erodibility of self-mulching clays depends on the size of the particles created when clay mulches. The default value for self-mulching clays is (2).

Table 2.22d. Susceptibility of land units to wind erosion using landform and wind erodibility rating from Tables 2.22a, b, or c

Landform[1]	Wind erosion hazard rating				
	Low (L)	**Moderate (M)**	**High (H)**	**Very high (VH)**	**Extreme (E)**
A. Foredunes and blowouts (BEA, BLO, FDL, FDH)	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
B. Crests and rises (CLI, LRI, RCR, RIS, SL_C)	**(1), (2)**	**(3)**	**(4)**	**(5)**	-
C. Flats and slopes (FPD, FPP, FWD, FPW, SL_L, SL_1, FOS, FOW, SL3, SL_5, SL_10, SL_15, SL30, SAS) and larger swamps and salt lakes (SWM, SAL)	**(1), (2), (3)**	**(4)**	**(5)**	-	-
D. Depressions (CDE, DDP, DDW, SWL, STC) and smaller swamps and salt lakes (SWM, SAL)	**(1), (2), (3), (4)**	**(5)**	-	-	-

[1] See Table 1.5e.

NOTE: (For soil-landscape system, map unit or site specific assessments)

1. If the landform experiences higher than average wind exposure, move up one row (e.g. from row C to row B).
2. If the landform experiences lower than average wind exposure, move down one row (e.g. from row C to row D).
3. If the landform experiences high waterlogging, the soil's erodibility is reduced by 1 unit, e.g. from (5) to (4). Excludes very shallow (VSH) soils which will dry off rapidly in summer.