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An Assessment of soil capability for on-site effluent disposal, East Carnarvon, Western Australia

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

Summary

The capability of soils in East Carnarvon for on-site effluent disposal is assessed primarily in terms of their absorption ability, purification ability and relative ease of excavation. It is considered that soils over the major part of the area have a high capability for this use. This assessment however makes no attempt to account for socio-economic factors such as the relative cost of providing a deep sewerage system at different levels of subdivision intensity, or the population which could be accommodated in the area with or without such a system.

Areas of low capability do exist and specific locations are highlighted. These correspond to soils where effluent absorption would be restricted by the relatively impermeable nature of clays, or dense clay barns, at the depth required for leach drain installation. These conditions were met at three of the ten sites examined. This does not necessarily mean that 30% of the area is so affected. Accurate delineation of the extent of these low capability areas is possible only with more intensive sampling on a grid basis.

In the areas of low capability it could be possible to overcome the problem of poor soil absorption through appropriate with design or site modifications. These might include:

- increased lengths of leach drains for conventional systems (possibly requiring larger lot sizes)
- use of alternating soil absorption systems
- use of systems designed with a significant evapotranspiration component and with growth of appropriate shrubs or trees nearby
- deep ripping and incorporation of gypsum into clay layers to improve permeability.

In addition to these factors the useful life of any system could be extended through a requirement for regular maintenance and pumping out.

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1. Introduction

This report arises from requests by both the Water Authority of Western Australia and the Shire of Carnarvon to assess the capability of soils in the East Carnarvon area (Figure 1) to be used for on-site disposal of septic tank effluent. At the time of these requests the Department of Agriculture was engaged in the description and mapping of soil and land types in the Carnarvon Land Conservation District with the objective of providing land resource data to assist land use planning. The relatively low intensity of site observation, commensurate with the proposed scale of the Land Conservation District mapping, was increased for the East Carnarvon area. The site descriptions were also supplemented with field measurements of the soil's saturated hydraulic conductivity at five locations. Due to time constraints the assessment was based on the available existing information rather than on a definitive lot by lot examination of soil conditions.

The Water Authority requested the work to identify areas which, from soil type:

(i) may be suitable for the permanent operation of septic tanks and on-site effluent disposal systems;

(ii) are not generally suitable for use of septic tank systems or only for short term operation;

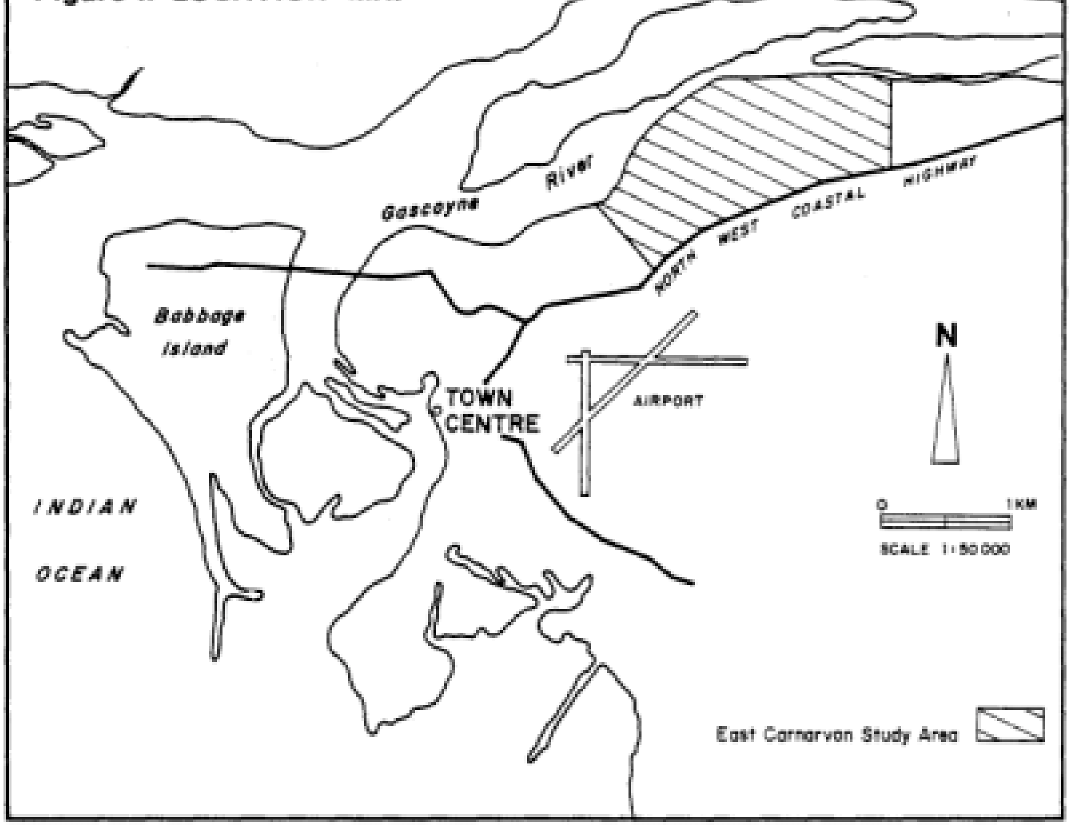
(iii) are not suitable for septic tank systems due to the proximity of the water table;

(iv) have particular features which could limit performance or make installation expensive.

This report addresses these points on the assumption that a conventional system for the on-site disposal and treatment of domestic liquid waste, consisting of one or more septic tank units followed by a sub-surface soil absorption system is to be used (Figure 2). Within the Carnarvon area the most commonly used sub-surface soil absorption system is a 12 m leach drain. The design of the drain is such that, whilst not being a complete evaporation - transpiration - absorption (ETA) process, the system operates with some evaporation-transpiration component (Carnarvon Shire Health Surveyor pers. comm.).

The general approach taken for this study was to provide, from the Department's current land resource survey, a brief description of the relevant soil and landform conditions in the East Carnarvon area. Using that data the area's capability for on-site effluent disposal was assessed according to both the criteria developed within the Department of Agriculture (Wells '987) and that contained within the Western Australian Health Act 1911-1973 (Department of Public Health undated).

Figure 1. LOCATION MAP



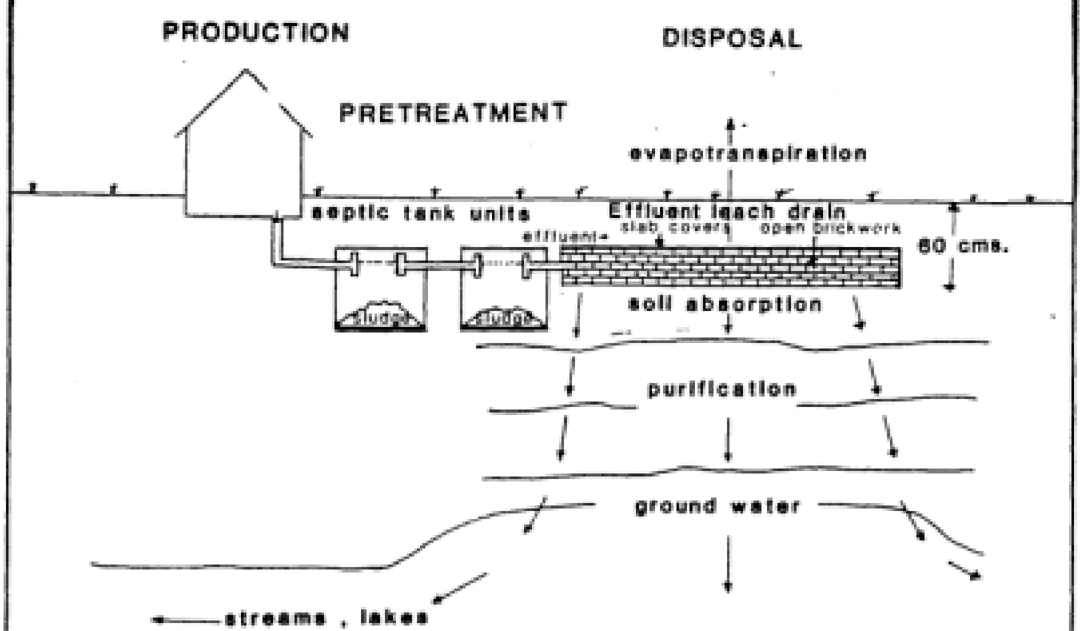


Figure 2 Schematic diagram of conventional septic tank system.

2. Method

2.1 General

Within the East Carnarvon area ten soil sites were described and of these four were chosen for in situ measurement of saturated hydraulic conductivity (Figure 3). The sites were chosen following stereoscopic aerial photo examination to determine topographic or remnant vegetation differences within the study area, and in an attempt to allow examination of a representative cross section of site conditions.

Soil profiles were described from hand auger borings according to the techniques and standards of the Australian Soil and Land Survey Field Handbook (McDonald et al.. 1984). Auger borings were made to 150-200 cm depth unless the presence of a dense subsoil clay layer prevented further examination. Data required for standard soil description and classification include the depth, texture, colour, consistence, structure, fabric and pH of all observable layers or horizons within the soil. These data, in conjunction with measurements of soil surface and landform properties, enable an assessment to be made of the major land qualities which affect effluent disposal. These qualities are the soil's absorption ability, its purification ability, and the relative ease of site excavation for septic tank or leach drain installation.

Of these qualities, it is the absorption ability of soil which is most commonly used to determine the suitability or otherwise of a site for effluent disposal. Whilst a qualitative assessment of absorption ability can be obtained from standard soil survey information, in cases where there is a degree of doubt over site suitability it is desirable to supplement the qualitative assessment with some quantitative data. For this reason hydraulic conductivity measurements were undertaken. Hydraulic conductivity, is regarded here as being roughly synonymous with permeability.

The hydraulic conductivity of a soil, K, in m/day defines the volume of water which will pass through unit cross-sectional area of a soil in unit time, given a unit difference in water potential. This parameter is commonly measured in agricultural soil studies to provide a guide to water movement and possible drainage problems within soil profiles, and also as a basis for in-field drainage design.

With respect to the ability of soil to absorb septic tank effluent, hydraulic conductivity is related to the rate at which effluent can flow away through the soil in both vertical and horizontal directions from the leach drain. The conductivity of a soil is also correlated to some extent with the long term infiltration rate of effluent into that soil and is therefore a parameter that should be determined or estimated for all soil layers at or near absorption trench level (Brouwer and Bugeja 1979).

There are basically two methods for measuring soil hydraulic conductivity above the water-table. One method consists of boring a hole to a given depth, filling it with water and measuring the rate of fall of the water level (Inverse auger-hole method, or Porchet method - Van Hoorn 1979). The other method uses apparatus to maintain a constant depth of water in the test hole whilst measurement is made at the rate at which water must flow in, to maintain the constant level (Modified well permeameter test - Talsma and Hallarn 1980).

Hydraulic conductivity was measured during the study of the East Carnarvon area using the method of Talsma and Hallarn (1980). To approximate the operating depth of an effluent disposal leach drain, soil hydraulic conductivity was measured for the 30-70 cm depth interval at each of the four locations. At one of these, an additional measurement was made for the 110-150 cm depth interval in order to characterize likely conditions beneath the drain. Although Talsma and Hallam's method was used for this study, mention has been made here of the other method as it is relevant to the soil absorption assessment criteria used by the Department of Health which will be discussed later in this report.

2.2 Land capability assessment

Land capability is a term used to express the ability of land to support a particular type of use without causing permanent damage. Assessment of land capability involves a comparison of the physical requirements for a particular use (in this case, on-site effluent disposal) with the existing qualities of the subject land. A five class system, which focuses on land use limitations and risks of land (and water) degradation, is employed by the Department of Agriculture to express land capability (Table 1).

Land qualities are complex attributes which act in a manner distinct from the actions of other land qualities in their influence on the capability of land for specified kind of use (FAO 1983). An example is, 'ease of excavation'. The list of land qualities which are considered in the Department's assessment method, and the related land use requirements for on-site effluent disposal are shown in Table 2. Land characteristics are attributes of land that can be measured or estimated, and can re used to describe land qualities. An example is 'depth to rock'. The land characteristic data, obtained from the land resource survey, are shown in Table 3. The specific methods to determine such values are given in Appendix 2.

The capability rating for a subject area of land is determined using a land use capability rating table (Table 4). This table is an expression of the land use requirements. The range of each land quality that influences the installation and operation of an effluent absorption system is divided into classes, each class representing a degree of limitation. At a particular site (or for a particular map unit) the values for land qualities (determined from tables in Appendix 2) are compared with the capability rating table; the most limiting land quality determining the overall capability classification. Further details of the land canability assessment system for on-site effluent disposal are given by Wells (1987).

A capability class (I to V) expresses the severity of the land use limitations and a sub-class (letter postcript) may be employed to indicate the nature of the limiting land quality (e.g. a = soil absorption ability). Thus, land rated classes I or II will have qualities which generally meet the requirements of the proposed land use (on-site effluent disposal) with few, if any, limitations or land degradation problems. Land rated classes IV or V is less able to meet the land use requirements. In these classes it is considered that there are severe limitations or land degradation hazards which may be impossible to overcome, or at least will require substantial modifications to the proposed form of land use.

Table 1. General land capability class definitions

Capability class	Degree of limitation	General description
I	None to very slight	Very high capability for the proposed activity or use. Very few physical limitations present which are easily overcome. Risk of land degradation is negligible.
II	Slight	High capability. Some physical limitations affecting either productive land use or risk of land degradation. Limitations overcome by careful planning.
III	Moderate	Fair capability. Moderate physical limitations significantly affecting productive land use or risk of land degradation. Careful planning and conservation measures required.
IV	High	Low capability. High degree of physical limitations not easily overcome by standard development techniques and/or resulting in a high risk of land degradation. Extensive conservation requirements.
V	Severe	Very poor capability. Severity of physical limitations is such that its use is usually prohibitive in terms of either development costs or the associated risk of land degradation.

Table 2. Land qualities and land use requirements for on-site effluent disposal

Land quality	Requirement
Absorption ability	Soil should be able to effectively absorb, and hence dispose of, the volume of effluent produced from all waste sources of a single family household (approx flow of 1000 L/d).
Purification ability	Soil should be able to effectively purify, largely by the process of absorption, microbial contaminants from effluent whose presence in groundwater systems may be hazardous to public health.
Ease of excavation	Soil and land surface conditions should be such that excavation for the installation of septic tank units and leach drains is not prohibitively expensive.
Water pollution risk - by overland flow - by subsurface leaching	Soil and land surface conditions should be such that nutrient loading of nearby surface waterbodies or groundwater supplies is not adversely affected. (The major nutrients of concern are phosphorus and nitrogen and the importance of this requirement relates to the significance and current or likely use of the waterbody or groundwater resource).
Flood hazard	The subject area should not be affected by a frequency or duration of flooding which would prevent effluent disposal systems from operating and hence pose a risk to public health.

Table 3. Land characteristics used to assess qualities which affect effluent disposal capability

Land qualities	Land characteristics
Absorption ability	• Site drainage/depth to seasonal water table • Permeability • Depth to impermeable layer • Stone content
Purification ability	• Permeability • Nature of soil; texture and coherence • Depth to impermeable layer • Site drainage • Slope
Ease of excavation	• Depth to rock • Slope • Stone content • Rock outcrop • Site drainage
Water pollution risk [1]	(by overland flow) • Absorption ability • Runoff (by subsurface leaching) • Nature of soil; texture and coherence
Flood hazard	• Landform/topographic position[2] • Field observation of flood events

Assessed for units at margins of waterbodies, streams and rivers or where land units overlie superficial groundwater aquifers where nutrient loading is of concern.

Correlated with W.A.W.A. flood study mapping.

Table 4. Land capability rating table for on-site effluent disposal areas capable of being used for soil absorption and purification of septic tank effluent from a single family dwelling

Land qualities		Rating [1] 1	2	3	4	5
		(Nil	Degree of limitation		..... Severe)	
Soil absorption ability	a	High	Moderate	Low	Very low	-
Soil purification ability	p	High	Moderate	Low	Very low	-
Ease of excavation	x	High	Moderate	Low	Very low	-
Water pollution risk [2]						
- by overland flow	o	Very low	Low	Moderate	-	High
- by subsurface leaching	s	-	Low	Moderate	-	High
Floor hazard	f	-	-	Low	Moderate	High

Notes

Capability class, expressed in Roman numerals, is determined by the most limiting rating.

Pollution risk considerations generally only apply to map units at margins of a waterbody or overlying superficial aquifers which feed into environmentally sensitive waterbodies.

3. Results

3.1 Description of the land

The study area occurs on an alluvial levee formed by riverine deposits of the Gascoyne River. The soils have been previously mapped at a very broad scale (1:126720) by CSIRO (Bettenay get al.. 1971). At that mapping scale the entire study area is represented by the Gascoyne soil association which is described as mainly brown uniform profiles with textures varying from loamy fine sand (Uc5.32*) to silty barns (Um5.2) and silty clay barns (Um5.12). The original vegetation of the area is likely to have been a moderately close, tall shrubland or woodland of acacias with fringing communities of coolibah and rivergum (Payne. 1987). At the time of this survey the area was almost entirely cleared and partly urbanized. The area has been extensively used for irrigated horticulture in the past and at least one plantation remained at the time of the survey.

The results of the land resource survey investigation of the East Carnarvon area are shown on Figure 3. The area has been subdivided into four topographic units by aerial photo interpretation. For each unit the soils are described on the basis of a limited number of sites within the study area, and by extrapolation of data from sites described elsewhere during the Department's broader scale survey of the Land Conservation District.

The only significant relief in the study area is offered by the low, very gently undulating dune ridges (map units A and B, Figure 3) which are up to an estimated 6m relief with slopes ranging from 1 to 5%. The soils are deep to very deep, rapidly drained, brownish siliceous sands or sandy barns (Ucl.23). They are very permeable and exhibit a neutral soil reaction trend. Little if any rainfall runoff is generated from these areas.

The major part of the study area consists of alluvium (map unit C, Figure 3) which is variable in terms of the soil's texture and drainage characteristics. The absence of original vegetation and the degree of land disturbance over much of this area makes it impossible to distinguish any surface expression of soil properties relevant to the study. Eight sample sites located to give a broad cross-section of the area reveal, to some extent, the degree of soil variation (Tables 5a and 5b).

Tables 5a and 5b also summarise the hydraulic conductivity measurements. These values generally fall at the lower end of the range of variation expected for each soil texture type according to published literature (Dent and Young 1981). It is suggested that the low values are the ~ of soil compaction and hardpan formation due to past cultivation and/or traffic pressure. This is supported by research at the Carnarvon Agricultural Research Station (Department of Agriculture 1986) which shows hydraulic conductivity values as low as 0.06 m/day in areas subject to frequent tractor traffic, where the soils might otherwise be expected to have values in the range of 0.5 to 1.5 m/day based on their texture. The trials also showed that permeability in these soils can be significantly improved through deep ripping and the application of gypsum.

* Principal Profile Form classification according to Northcote (1969) - Further description of soils classified under this system may be found in Northcote et al. (1975).

The most common soils of map unit C (Figure 3) are uniform reddish brown non calcareous barns (Um5.2) consistent with the medium textured variety of the Gascoyne soil association. These soils are deep and generally well drained, with moderate to moderately rapid permeabilities, and neutral to slightly alkaline reaction trends. They are either weakly structured or massive with a porous, earthy fabric. Site 426 is considered a typical Gascoyne soil, site 427 being a heavier (more clayey) variant, and sites 385 and 386 show that in some areas the soil may occur on top of other alluvial sand or clay layers at varying depths. The soil and site 429 is an earthy loam with a red brown hardpan (Um5.3). The hardpan occurs beneath 60 cm depth and is likely to be the result of past cultivation and traffic effects.

Less commonly occurring within map unit C are the alkaline red duplex soils (Dr2.53) represented by sites 388 and 393, and a heavier textured variant of the Gascoyne Soil association with a traffic or cultivation induced hardpan within 60 cm depth (Um5.3) represented by site 387. These soils have a moderately slow to slow permeability due to dense, weakly structured subsoil clay or clay loam layers. The subsoil layers are slightly salt affected and the restriction to drainage may cause perched water tables to develop after significant rain periods. These soils represent an intergrade between the Gascoyne and Coburn soil associations (Bettenay et al. 1971).

The relatively bow site density and lack of surface vegetation or aerial photo pattern features prevent the drawing of a boundary between the two major groupings of soils within map unit C (Figure 3). The soil sites where drainage, and hence soil absorption, is likely to be limited have however been highlighted.

Table 5a. Variation in soil properties within map unit C - sites of high capability

Soil characteristic	**Site No.**				
	385	**386**	**426**	**427**	**429**
Surface texture	SL	LFSY	SL	SL	SL
Texture at 20-60cm	S	LFSY	LFSY	ZL	SCL
Texture below 60cm	ZL-LC	S-CLFS	LFSY-FSL	ZCL-CL	?hardpan
Soil permeability*					
-assessed	Mod rapid	Moderate	Moderate	Moderate	Moderate – Moderately Slow
- measured (hydraulic conductivity)	0.79 m/day 0.01 m/day**	-	0.28 m/day	0.20m/day	-

* Refer to Appendix 2 for correlation between assessed and measured values.
** Measurement within subsoil clay, all other made at approximate depth of leach drain.

Table 5b. Variation in soil properties within map unit C - sites of low capability

Soil characteristic	**Site no.**		
	387	**398**	**393**
Surface texture	LFSY	CL**	SL
Texture at 20-60 cm	LSFY-LC	LC	MC
Texture below 60 cm	LC	LC	LMC
Depth to clay (cm)	40	5	10
Soil permeability*			
- assessed	Mod slow-Slow	Slow	Slow
-measured (hydraulic conductivity)	0.01 m/day	-	-

* Refer to Appendix 2 for correlation between assessed and measured values.
**Not considered to be the original surface – site disturbed.

Textures	
S	Sand
SL	Sandy loam
LFSY	Loam fine sandy
FSL	Fine sandy loam
SCL	Sandy clay loam
ZL	Silty loam
ZCL	Silty clay loam
CL	Clay loam
CLFS	Clay loam fine sandy
LC	Light clay
LMC	Light to medium clay
MC	Medium clay

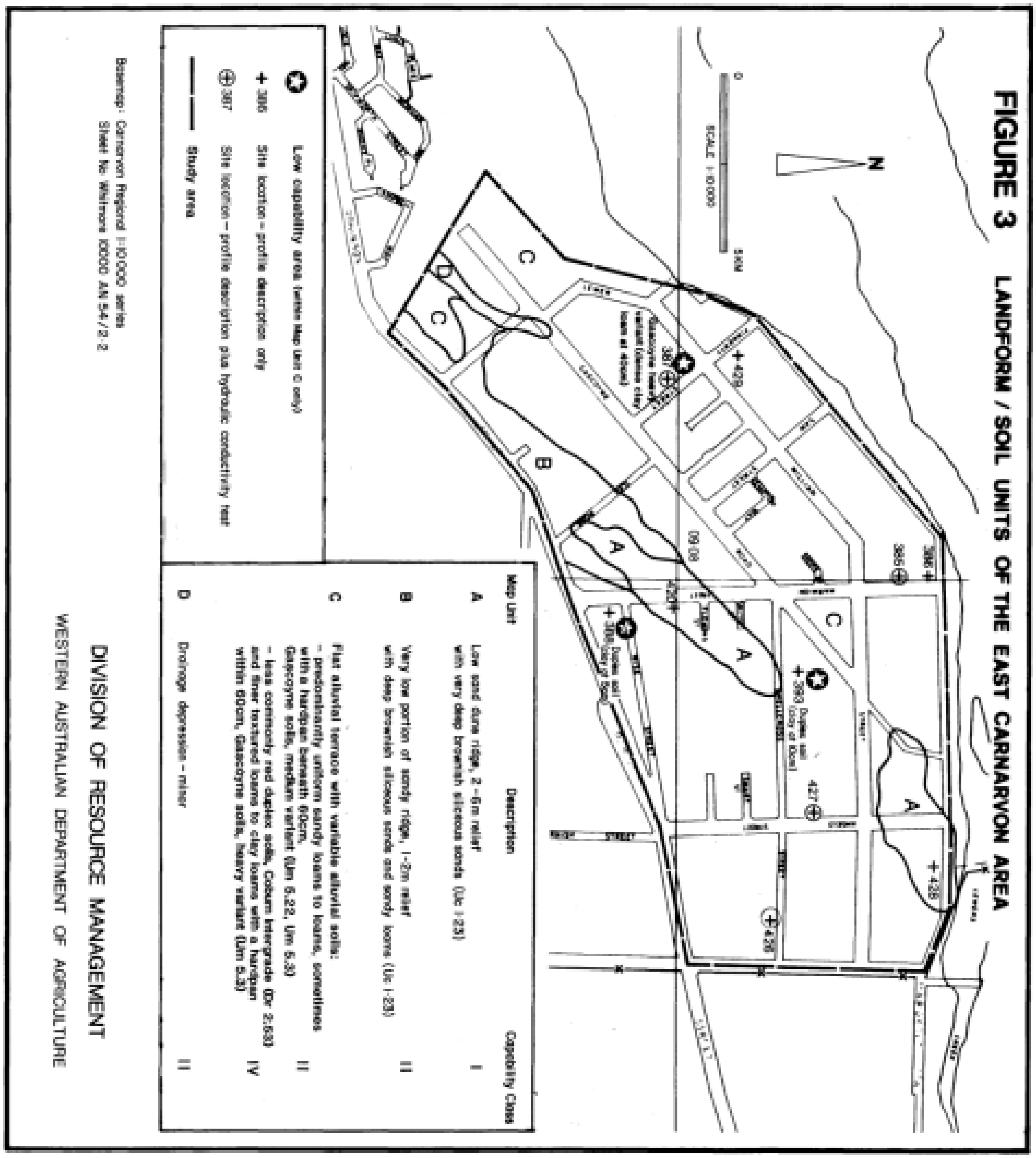


FIGURE 3 LANDFORM / SOIL UNITS OF THE EAST CARNARVON AREA
N
SCALE 1:10000
Map Unit
Description
Capability Class
A
Low sand dune ridge, 2–6m relief with very deep brownish siliceous sands (Uc 1.23)
I
B
Very low portion of sandy ridge, 1–2m relief with deep brownish siliceous sands and sandy loams (Uc 1.23)
II
C
Flat alluvial terrace with variable alluvial soils:
– predominantly uniform sandy loams to loams, sometimes with a hardpan beneath 60cm, Gascoyne soils, medium variant (Um 6.22, Um 5.3)
II
– less commonly red duplex soils, Coburn intergrade (Dr 2.63) and finer textured loams to clay loams with a hardpan within 60cm, Gascoyne soils, heavy variant (Um 5.3)
IV
D
Drainage depression – minor
II
Low capability area (within Map Unit C only)
Site location – profile description only
Site location – profile description plus hydraulic conductivity test
Study area
Basemap: Carnarvon Regional 1:10000 series
DIVISION OF RESOURCE MANAGEMENT
WESTERN AUSTRALIAN DEPARTMENT OF AGRICULTURE

3.2 Capability assessment

3.2.1 Assessment using Department of Agriculture system

Under this system five land qualities are normally assessed to determine land capability for effluent disposal from septic tanks. These are:

- absorption ability, purification ability,
- ease of excavation,
- water pollution hazard and flood hazard.

For this assessment of the East Carnarvon area however, flood hazard is not relevant due to the presence of a protective levee system.

Water pollution risk by nutrient enrichment has also not been directly considered in the capability rating. Although both phosphorous and nitrogen are present in high amounts in septic tank effluent (Whelan et al.. 1981) phosphorus travel appears to be very limited except under saturated circumstances in coarse sandy soils. Brouwer and Bugeja (1979) report that although nitrate-nitrogen travel is very extensive, it must be kept in mind that water flow is the vector and in many Australian situations, there may be little or no flow of soil water or effluent for any significant distance from an absorption field. This would appear to be the case in East Carnarvon given the presence of loamy to clay subsoils over most of the area.

Water pollution by nutrient enrichment need not be considered further because the underlying groundwater resource in this area is not used for drinking water. There are also no open water bodies in the vicinity where eutrophication might result from nutrient enrichment. Should the issue still cause concern, it is suggested that the appropriate criteria to use is a minimum depth to the water table of 1.2 m below the base of the leach drain (Wagner and Lanoix 1958). The land resource survey in this area did not obtain information on the depth to groundwater.

The capability assessment is therefore primarily based on three land qualities, absorption ability, purification ability and ease of excavation. Table 6 summaries the land quality values and capability ratings. Using the criteria in Appendix 2 band quality values have been determined for each map unit, and within the variable map unit C they have been determined for each specific site. The capability rating is derived by matching these values against those in the capability rating table (Table 4).

The results in Table 6 indicate that soils over the major part of the East Carnarvon area are likely to have a high capability for effluent disposal. Within the most extensive map unit (C) there are areas which have a low capability (Class IV). These sites are indicated on Figure 3. A more accurate delineation of these low capability soils is not possible without an intensive grid survey concentrating on the depth to clay or hardpan layer.

Table 6. Land qualities and capability ratings

		Land qualities[1]			
Map Unit	**Site no.**	**Soil purification ability –p**	**Ease of excavation –x**	**Soil absorption ability – a**	**Capability rating[3]**
A	420428	High	High	High	I
B		Moderate	High	High	II
C	385	High	High	Moderate[2]	II
	386	High	High	Moderate	II
	387	Moderate	High	Low-very low[2]	IVa
	388	Low	Moderate	Low-very low	IVa
	393	Low	Moderate	Low-very low	IVa
	426	High	High	Moderate[2]	II
	427	High	High	Moderate[2]	II
	429	Moderate	Moderate	Moderate	II
D		High	Moderate	Moderate	II

1. Values for land qualities determined by comparing site or map unit date with tables in Appendix 2.
2. Absorption ability principally determined by hydraulic conductivity measurements.
3. Capabilities rating determined b matching land quality values against positions in Table 4. Sub class postscripts are shown for low capability sites (e.g. a = Absorption ability).
   I = very high capability, II = High capability, IV = low capability.

3.2.2 Assessment using Department of Health criteria

Within Western Australia septic tank systems are constructed and operated to standards specified on the Bacteriolytic Treatment of Sewage and Disposal of Effluent and Liquid Waste Regulations 1973. With respect to the capability of soil, schedule G of these regulations (Appendix 1) describes a technique to determine the absorption capacity of the soil. Using this technique a soil with a percolation rate of less than 2.5 cm per hour is deemed unsuitable for use as an effluent disposal field.

Percolation rate is however not an intrinsic soil property and can vary with different sized test holes and with wetting depth. With a knowledge of the test hole dimensions the recommended minimum percolation rate can be converted to an unambiguous saturated hydraulic conductivity figure (refer Appendix 3). For Western Australia this minimum rate is equivalent to a saturated hydraulic conductivity of 0.25 m/day. This compares with a figure of 0.21 m/day used in Victoria (E.P.A. Victoria figure quoted in Brouwer et al.,. 1982) and 0.10 day/day used in the United States (Otis et al. 1980).

Using these criteria the hydraulic conductivity results in Table 5 show that the duplex soil types and the heavier Gascoyne soil variant are likely to fail the test. For site 427 the result is considered marginal in view of the limited number of site replications and due to the inherent variability of individual hydraulic conductivity values made by any field method. Generally however, an assessment of the results according to Department of Health criteria is consistent with one which uses the Department of Agriculture’s system. It is the soils where a clay or dense clay loam hardpan layer occurs within the depth to be occupied by leach drains, that have a low capability for on-site effluent disposal.

4. Discussion

4.1 General

This assessment of soil capability for on-site effluent disposal in East Carnarvon focuses on the ability of the soils to be used for that purpose based on three primary factors - their absorption ability, their purification ability and their relative ease of excavation.

In deriving the capability ratings no account is taken of socio-economic factors. The most notable of these factors is the relative cost of providing a reticulated sewerage scheme to the area. At present there is relatively little land subdivision and development although some time in the future intensive development may occur. More intensive subdivision, and hence a greater population, could be accommodated in the area if it. were skewered, compared to the present situation where relatively large lot sizes are dictated by the need for areas free of buildings, sheds, pools etc. for soil based effluent disposal systems.

4.2 The role of evapotranspiration

The evaluation of land for septic effluent disposal depends on the ability of soils surrounding leach drains to absorb liquid effluent. Current standards relate to minimum permissable hydraulic conductivities of 0.25 day/day in Western Australia and 0.21 day/day in Victoria. Research has shown however, that disposal fields in Victoria can function quite well on soils with lower conductivities (Brouwer et al. 1979, Brouwer and Bugeja 1979, van de Graaff et al. 1980). This is explained by Brouwer et al. (1982) as being due to the role evapotranspiration plays in effluent disposal by leach drains.

In contrast with the United States where much of Victoria and Western Australia's effluent disposal design criteria originated, Australian winters are relatively mild, potential evaporation in winter is still appreciable, and trees and shrubs are mostly non-deciduous. In the Carnarvon area, with a semi arid climate the role of evapotranspiration in supplementing the soil absorption process is likely, depending on the system design, to be substantially greater than that observed in Victoria. As a result assessments based on absorption criteria alone may penalise development using septic tanks.

4.3 Addressing Water Authority queries

4.3.1 Areas which may be suitable on a permanent basis

The soils of map units A and B, and the light to medium textured Gascoyne soils (major areas) within map unit C, are most capable of being used for effluent absorption. The length of time any soil absorption system can operate is a matter of conjecture and will be related to the adequacy of the original design criteria and the frequency of maintenance.

In the recent report of the Select Committee appointed to inquire into effluent disposal in the Perth Metropolitan Region (Alexander 1988) it was considered that septic tank systems in their present mode (as in Carnarvon) are unacceptable as a long term effluent disposal solution, and that even in areas of suitable soil and site conditions, septic tank systems do not operate indefinitely and regular maintenance is required. This is supported by the Caldwell Connell Report (1986) which found that soil absorption systems progressively clog until relatively low equilibrium infiltrations are obtained. Whether or not these low equilibrium values are sufficient will depend on the adequacy of the original design, specifically trench length, and on the relative size of the evapotranspiration component in the process.

A somewhat contrary opinion to that of the Select Committee is offered by Brouwer and Bugeja (1979) who cite work by Machmeier (1975) and Healy and Laak (1974) as evidence, that as long as the field is not overloaded and the septic tank is regularly pumped out, the life span of an absorption field is indefinite. They consider however that as overloading may at times take place it may be wise to leave room for a replacement absorption field.

4.3.2 Areas generally not suitable or suitable for only short term operation

The duplex soils and heavier textured Gascoyne soils within map unit C would generally fit into this category. However it is important to realize that factors such as an increase in the size of an absorption field, and better management and maintenance of septic systems, can reduce the incidence of failure in these areas.

In their recent study of on-site waste water disposal systems, Caldwell Connell Engineers (1986) have prompted improvements to be made to the interpretation of the Health Department assessment technique. Loading infiltration rates for both alternating and non alternating leach drain systems are now related both to broad soil types and percolation rate criteria. For relatively impervious clay soils where the percolation rate is expected to be slower than 2.5 cm per hour, it is suggested that the soils in their natural state are unsuitable for on-site disposal and require system design and site modification (Department of Health - pers. comm.). This recognizes an important point that soil capability is not a clear cut factor. In any location where septic tanks are proposed, absorption field size, trench lengths and system types should be related to the land or soil conditions, and to the particular vegetation cover and climatic conditions. In other words, in most situations knowledge of the soil or land conditions can be used to 'design around' or overcome potential problems for effluent disposal.

4.3.3 Areas not suitable due to the proximity of the water table

For this survey, no specific data on the depth to the water table has been obtained in the East Carnarvon Area. The study concentrated on soil and landform properties. There was no evidence, in terms of either subsoil mott1~1g or vegetation indicator species, to suggest the presence of a water table within 1.8 m of the soil surface, other than as a temporary perching of water above the clay layer in duplex soils.

4.3.4 Areas with features which could limit performance or make installation expensive

The performance of effluent disposal systems is judged, more than any other single factor, on the ability of soils to adequately absorb effluent at the required loading rates. Within the study area performance is likely to be limited only by the duplex soil types or the heavier textured Gascoyne soils where clay, or dense compacted clay loam, layers occur within 60 cm of the surface. Sites where these conditions have been encountered are highlighted in Figure 3. Further delineation of these areas could only be made by systematic sampling on a grid survey basis.

References

Alexander, I. (1988). Report of the Select Committee Appointed to Inquire into Effluent Disposal in the Perth Metropolitan Region, Western Australia. A report to the Western Australian Legislative Assembly (August).

Bettenay, E., Keay, J. and Churchward, H.M. (1971). ‘Soils adjoining the Gascoyne River near Carnarvon, Western Australia’ Soils and Land Use Series No. 51. Division of Soils C.S.I.R.O. Australia.

Brouwer, J. and Bugeja R.M. (1979). Land capability for septic tank effluent absorption trenches. Report A.W.R.C. Project 79/118, State Rivers and Water Supply Commission, Armadale, Victoria.

Brouwer, J., van de Graaff, R.H.M., Bugeja, R.M., and Willatt, S.T. (1982). ‘On-site septic tank effluent disposal through soil absorption and evapotranspiration - a working model’. Paper presented at the Australian Soil Science Society Conference, Canberra - May 1982.

Brouwer, J.,, Willatt, S.T. and van de Graaff, R.H.M. (1979). The hydrology of on-site septic tank effluent disposal on a yellow duplex-like soil. Hydrology and Water Resources Symposium, Perth, W.A., Symposium papers, pp. 112-117.

Caldwell Connell Engineers Pty. Ltd. (1986). On-site wastewater disposal systems. Final Report to Water Authority of Western Australia, Perth.

Dent, D., and Young, A. (1981). Soil Survey and Land Evaluation. George Allan and Unwin (publishers) Ltd. London, p. 236.

Department of Agriculture (1986). Determinate Tomato Irrigation Trial (No.1 1986). Final (unpublished) report. Department of Agriculture, Carnarvon Office. File No. 426.05.

Department of Public Health W.A. (Undated). Bacteriolytic Treatment of Sewage and Disposal of Effluent and Liquid Waste Regulations. Schedule ‘G’ Department of Public Health.

FAO (1983). Guidelines : land evaluation for rainfed agriculture. Soils Bulletin No. 52. Food and Agriculture Organization of the United Nations, Rome.

Healy, K.A. and Laak, R. (1974). Site evaluation and design of seepage fields. J. Environ. Eng. Div. A.S.C.E. 100:1133-46.

Machmeier, R.E. (1975). Design criteria for soil treatment systems. Sci. J. Series Paper 9358, Minn. Agric. Ex. Stn. St. Paul, Minnesota.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1984). ‘Australian Soil and Land Survey Field Handbook’. Inkata Press Pty. Ltd., Melbourne.

Northcote, K.H. (1969). ‘A Factual Key for the Recognition of Australian Soils’. C.S.I.R.O. 4th Edition, Rellim Technical Publications Pty. Ltd., Adelaide, South Australia.

Northcote, K.H., Hubble, G.D., Isbell, R.F., Thompson, C.H. and Bettenay, E. (1975). ‘A Description of Australian Soils’. C.S.I.R.O.: Australia.

Otis, R.J., Boyle, W.C., Clements, E.V. and Schmidt, C.J. (1980). Design manual for on-site waste-water treatment and disposal systems. Published by the U.S. Environmental Protection Agency, Report No. EPA -625/1-80-012, 412 pp.

Payne, A.L., Curry, P.J. and Spencer, G.F. (1987). An inventory and condition survey of rangelands in the Carnarvon Basin, Western Australia. Technical Bulletin No. 73. Western Australian Department of Agriculture.

Talsma, T., and Hallam, P.M. (1980). Hydraulic conductivity measurements of forest catchments. Aust. *J.* Soil Research, Vol. 18, No.2, P. 139-148.

van de Graaff, R.H.M.., Brouwer J and Willatt, S.T. (1980). On-site septic tank effluent absorption - the effects of soil and band features. Paper presented at the national Soils Conference, Australian Society Soil Science Inc., Sydney.

van Hoorn, J.W. (1979). Determining hydraulic conductivity with the inversed augerhole and infiltrometer methods. Paper 1.06. In: Wesseling, J. (Editor). Proc. International Drainage Workshop, May, 1978, Wageningen. Publ. No. 25, International Inst. for Land Reclamation and Improvement, Wageningen, The Netherlands.

Wagner, E.G. and Lanoix, J. (1958). Excreta disposal for rural areas. Monograph No. 39. World Health Organization, Geneva.

Wells, M.R. (1987). Assessment of land capability for on-site septic tank effluent disposal. Technical Report No. 63. Division of Resource Management, Western Australian Department of Agriculture.

Wells, M.R. and King, P.D. (1988). Land Capability Assessment for Rural Residential Development and Hobby Farming. Technical Bulletin in preparation, Western Australian Department of Agriculture.

Whelan, B.R., Barrow, N.J. and Carbon, B.A. (1981). Movement of Phosphate and Nitrogen from Septic Tank Effluent in Sandy Soils near Perth, Western Australia. In: Lawrence, C.R. and Hughes, R.J. (eds). Proc. Groundwater Pollution Conference (1979). AWRC conf. series No. 1 pp. 391-401.

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Appendix 1 Schedule G from relevant Health Department Regulations

Schedule "G"
Health Department
FORMULA FOR DETRMINING ABSORPTIVE CAPACITY OF SOIL.

1. Dig a hole with dimensions of 300 mm square and vertical sides to the depth of the proposed absorption trench.

2. Carefully scarify the bottom and sides of the hole in order to remove any smeared soil surfaces and to provide a natural soil interface into which the water may percolate. Remove all loose material from the hole. Add 50 mm of blue metal, or screened gravel, to protect the bottom from scouring and sediment.

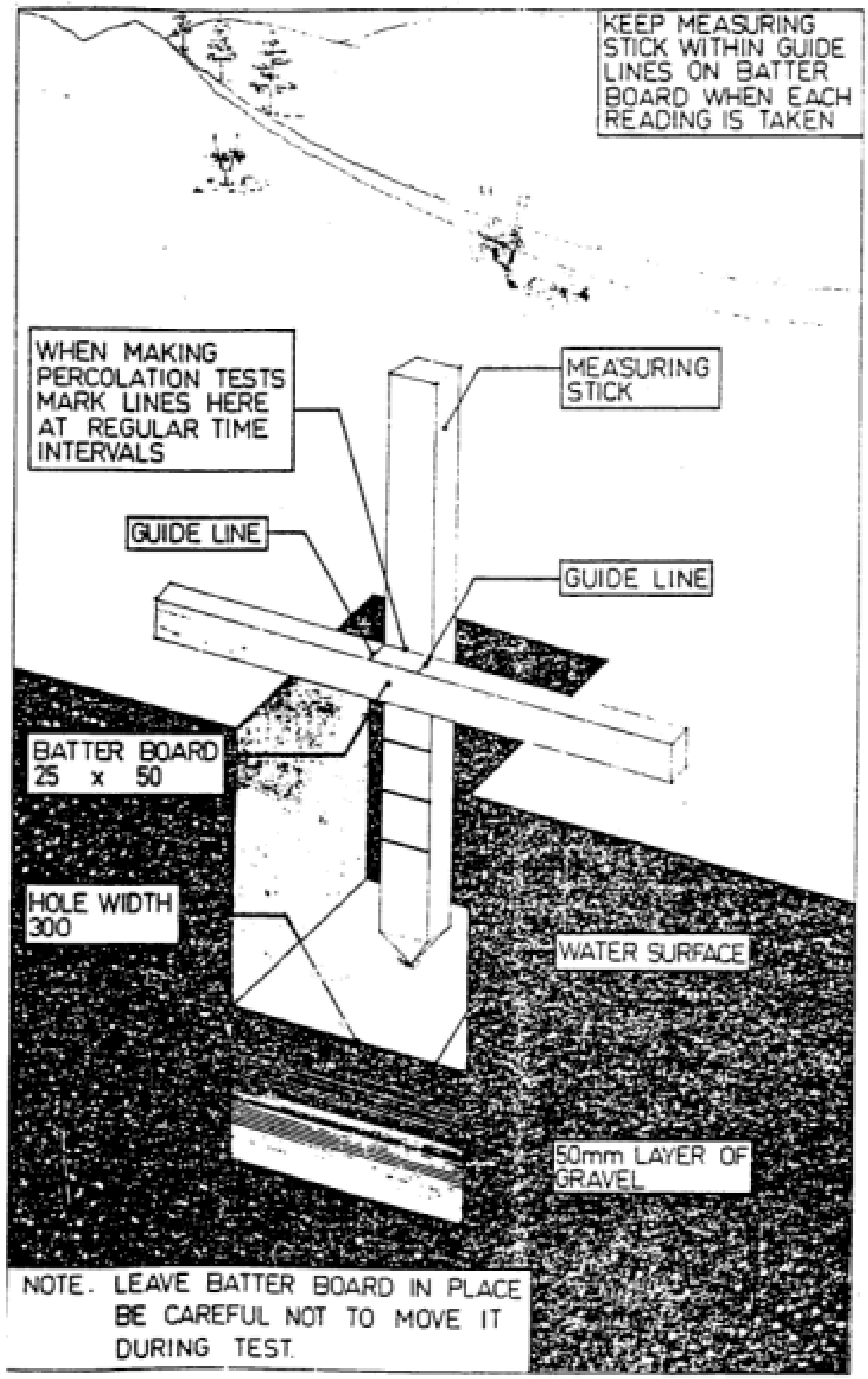
3. Fill the hole with water and allow it to soak away. Preferably keep the hole filled overnight. possibly by means of an automatic siphon.

4. The following morning, fill or adjust water level to a depth of 150 mm above blue metal or gravel, insert measuring stick (as shown) and note time taken for water to fall *25* mm.

The amount of effluent which can be disposed of per square metre of trench bottom per day is given by the following table:-

Time for water to Fall 25 mm.	**Dose per 0.09 square metre of Trench Bottom.**
1 minute	14 litres
2 minutes	11 litres
5 minutes	10 litres
10 minutes	7 litres
30 minutes	3.5 litres
60 minutes	2 litres
Over 60 minutes	Soil unsuitable.

The use of a diversion pit and stop board to divert drainage from one line of drain to another is recommended where large quantities of water are to be disposed of into difficult soils.



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Appendix 2: Assessment of Land Qualities

The following tables, reproduced from Wells and King (1988) illustrate how values can be determined for land qualities, from land characteristic data. The standard terminology used to describe each land characteristic is defined in the Australian Soil and Land Survey Handbook (McDonald et al. 1984).

Table A2.I Assessment of land quality - Absorption ability[1]

Land characteristic	Rating			
	High	**Moderate**	**Low**	**Very low**
Permeability class.	Very rapid-Rapid	Moderate-Moderately rapid	Moderately slow	Slow
(Hydraulic conductivity)[2]	> 1 m/day	0.05 1 m/day	0.01-05 m/day	< 0.01 m/day
Drainage class[3]	Well-Rapid	Moderately well – Imperfect	Poor	Very poor
Depth to impermeable layer	Deep	Moderately deep	Shallow	Very shallow
Stone within profile	Nil – Common	Many	Abundant	Very abundant

NOTES:

1. The rating will be determined by that of the most limiting land characteristic

2. Permeability is a composite expression of soil properties and depends largely on soil texture, soil structure, the presence of pans and the size and distribution of pores in the soil. Permeability categories are essentially ranges of hydraulic conductivities. Permeability categories are assigned during a soil survey based on a consideration of the above factors. Where hydraulic conductivity measurements have been made these can be used in lieu of the empirical assessments of permeability category.

3. For many soil surveys drainage class will need to be used in lieu of ‘depth to seasonal water table’. If however, sufficient depth data are available, Department of Health criteria should be used for site specific assessment. i.e. 1.2 m below base of effluent leach drains, or 1.8 m below soil surface is sufficient, and for the purpose of determining a capability rating, absorption ability is automatically high.

4. If the absorption ability is low or very low there will be a high risk of on-site pollution.

Table A2.2 Assessment of land quality - Soil purification ability

Permeability (hydraulic conductivity)	**Nature of soil**	**Depth to impermeable layer[1]**	**Rating [2, 3]**
Moderately rapid – Very rapid (. 0.5 m day^{-1})	(i) Sands: Grey or very pale leached sands with little coherence, and calcareous sands.	> 5 m < 5 m	Low Very low
	(ii) Coloured sands (usually yellowish brown to red) and earthy sands with slight to moderate coherence.	> 2 m 1 – 2 m < 1 m	High Moderate Low
Moderate – Slow (< 0.05 m day^{-1})	Soils with loamy textures or heavier	> 1 m 0.5-1 m < 0.5 m	High Moderate Low

1. Depth to rock, impermeable poor structured clay, or seasonal water table if known.
2. If site drainage is very poor soils will be insufficiently aerated for bacterial breakdown of effluent components. Rating is automatically very low.
3. On steep slops where permeability is moderate-slow, lateral seepage may intercept the surface resulting in ineffective purification. Where soils have a moderate-slow permeability and slope is 20-30%, the rating is automatically low. If slope is > 30% rating is very low.

Table A2.3 Assessment of land quality - Water pollution risk by overland flow

Absorption ability[1]	**Runoff rate**	**Risk rating**
High	-	Very low
Moderate	Nil-Slow	Low
	Moderately rapid – Very rapid	Moderate
Low or Very low	Nil-Slow	Moderate
	Moderate rapid – Very rapid	High

1. Determined from Table A2.1
2. If the site is subject to a high flood hazard, the pollution risk rating is automatically very high. For a moderate flood hazard it is high. For a low flood hazard, it is moderate.

Table A2.4. Assessment of land quality - Water pollution risk by subsurface beaching

Soil description	Nutrient retention rating	Pollution risk rating
Deep grey leached siliceous sands where iron-organic pans, if present, are weak and occur at depths greater than 1 m.	Very low	High
Grey leached sands or sandy loams with iron-organic hardpan within 1 m. Duplex soils with moderately deep (50-100 cm) sandy leached topsoils, or sands of similar depth overlying unrelated clay Shallow gravelly sands over rock.	Low	High
Sands and earthy sands with coloured subsoils. Deep gravelly sands or gravelly duplex soils. Calcareous sands. Duplex soils with shallow (c 50 cm) top soils.	Moderate	Moderate
Uniform loamy soils. Gradational earths.	Moderately high	Low
Uniform clay loams or clays.	High	Low

Table A2.5. Assessment of land quality - Ease of excavation

Land Characteristic	High	Rating[1] Moderate	Low
Depth to rock	Deep	Moderately deep	Shallow
Slope	0-10%	10-120%	> 20%
Stone within profile	Nil – Common	Many – Abundant	Very Abundant
Rock outcrop	Nil – Very few	Few	Common or more
Site drainage2	Rapid – Moderately well	Imperfect – Poor	Very poor

1. Rating determined by that of the most limiting land characteristic.
2. Affects need to shore up sides of excavation against collapse if excavation is undertaken during winter.

Table A2.6. Assessment of land quality - Flood hazard

Flood Hazard	Description
High	• lowest terraces and margins of major rivers and streams; • active floodways as defined by W.A.W.A.
Moderate	• intermediate level terraces of major rivers and streams, incised drainage lines, and minor valley floors
Low	• Higher terraces of major rivers and streams, non-incised ill defined drainage pathways associated with minor creeks and streams; • land occurring outside active floodway areas but within the 1:1000 year flood level as defined W.A.W.A. maps.

Appendix 3: Calculation of Hydraulic Conductivity from Health Department Minimum Percolation Rate Criteria

Within Western Australia the Health Department recommends that the suitability of soils for septic tank absorption systems be determined by measuring the time taken for water to fall 25 mm within a pre-wetted test hole with dimensions of 300 mm square and vertical sides to the depth of the proposed absorption trench. At the base of this hole 50 mm of blue metal, or screened gravel is added to protect the bottom from scouring and sediment. If the time taken for water to fall 25 mm exceeds 60 minutes the soil is deemed unsuitable (Refer schedule G. Appendix 1).

To commence the test water is added to 150 mm depth above the blue metal. Hence the initial wetting depth (h) for the percolation rate test is 150 + 50 = 200 mm and the total initial infiltration area is represented by ~.he four sides and base of a box shape with dimensions 300 x 300 x 200 mm. It is assumed that the coarse blue metal or screened gravel will do little to restrict the side wall or base area available for infiltration.

Knowing the dimensions of the test hole a minimum percolation rate of 25 mm/hr may be converted into an unambiguous saturated hydraulic conductivity by treating the test as 'inversed auger hole test' or 'Porchet test' (van Hoorn 1979). Calculations for the 'Porchet test' are however based on a round rather than a square test hole. Therefore to calculate the hydraulic conductivity the dimensions of a cylinder (round hole) must be determined which will give an equivalent infiltration area to that provided by the square hole. It is argued that this approach is valid since the process of infiltration is by radial flow and should be little affected by the shape of the hole given the same surface infiltration area (G. Aylmore, U.W.A. pers. comm.).

The calculations are as follows:

Infiltration area	=	area of side wall x 4 + area of base
of square hole	=	300 x 200 x 4 + 300 x 300 mm
	=	24,000 + 90,000
	=	330,000 mm^2

Equivalent cylinder	=	area of cylinder wall + area of base
area	=	$2 \prod r h + \prod r^2$
		where depth of wetting, h = 200 mm

$\therefore$ $330{,}000 = 400 \prod r + \prod r^2$

or $\prod r^2 + 400 \prod r (-330{,}000) = 0$

this quadratic equation being solved using the formula

$$r = \frac{- b \pm \sqrt{b^2 - 4 ac}}{2a}$$

where $a = \prod$, $b = 400$, $c = -330{,}000$

$$\therefore \quad r = \frac{-400 \pm \sqrt{400^2 - 4 \Pi (-330{,}000)}}{2 \Pi}$$

$$= \frac{-400 + \sqrt{160{,}000 + 1{,}320{,}000 \Pi}}{2 \Pi}$$

$$= \frac{-400 \pm \sqrt{160{,}000 + 4{,}146{,}902.3}}{2 \Pi}$$

$$= \frac{-400 \pm \sqrt{4{,}306{,}902.3}}{2 \Pi}$$

$$= \frac{-400 \pm 2{,}075.3}{2 \Pi}$$

$$= \frac{1{,}675.3}{2 \Pi} \qquad = \frac{1{,}673.3}{6.283} \qquad = 266.64 \text{ mm}$$

Radius of cylinder (round hole) of equivalent area to Department of Health's square hole test is 266.6 mm.

Using the Porchet method hydraulic conductivity K, is calculated using the formula

$$K = \frac{1.15\, r\, [\log (h (t_i) + r/2) - \log (h (t_n) + r/2)]}{t_n - t_i}$$

where radius of test hole r	=	26.664 cm
initial wetting depth $h(t_i)$	=	20 cm
final wetting depth $h(t_n)$	=	17.5cm (20 minus require fall distance of 2.5cm)
initial time t_i	=	0 sec
final time t_n	=	3,600 sec (1 hour)

$$K = \frac{1.15 \times 26.664\, [\log (20 + \frac{26.664}{2}) - \log (17.5 + \frac{26.664}{2})]}{3{,}600 - 0}$$

$$= \frac{30.6636\, [\log 33.332 - \log 30.832]}{3{,}600}$$

$$= \frac{30.6636\, [1.52286 - 1.489]}{3{,}600}$$

$$= 30.6636\, \frac{(0.03386)}{3{,}600}$$

$$= 30.6636\, (9405 \times 10^{-6})$$

= 0.000288 cm/sec

K = 0.249 m/day

i.e. A percolation rate of 25mm/hr within the test hole of dimensions required by Western Australian Department of Public Health is equivalent to a hydraulic conductivity of 0.249 m/day.