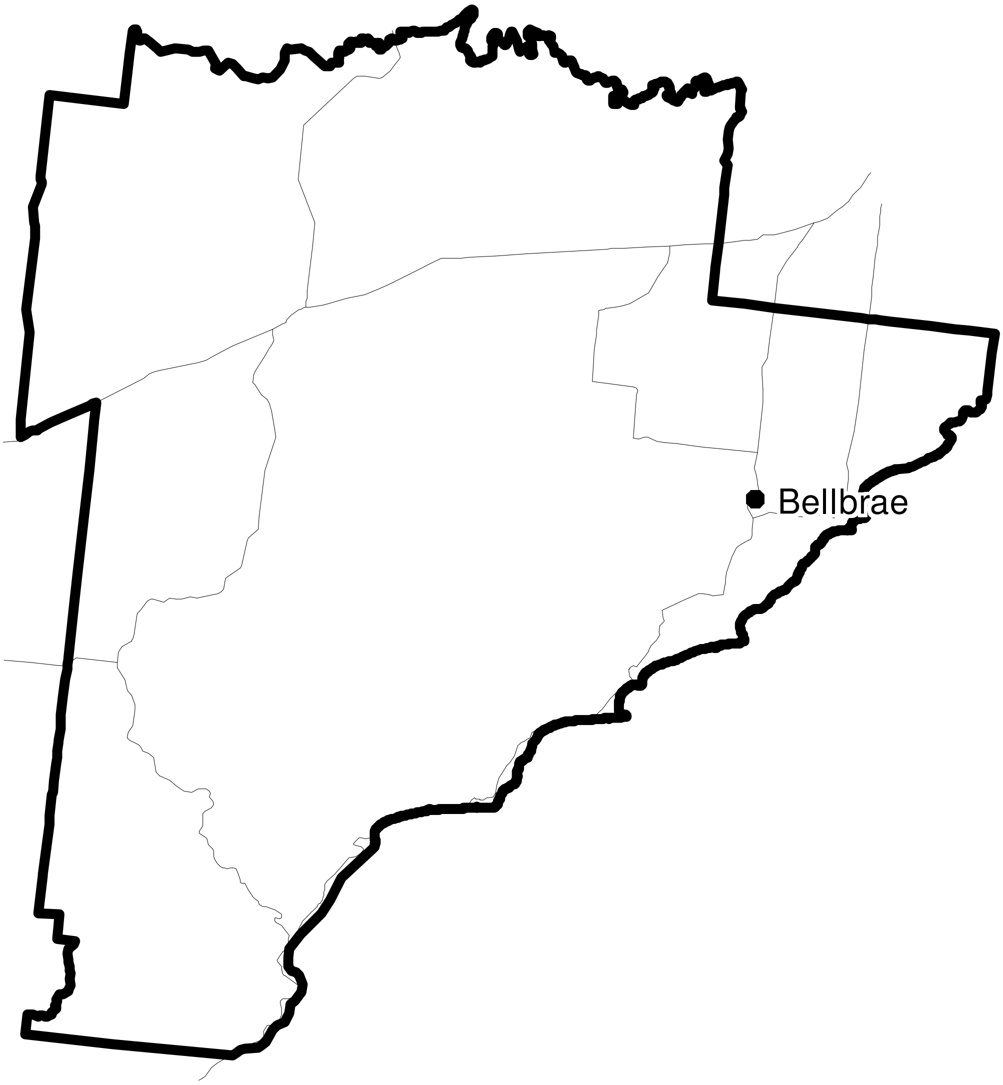

A Review Of Domestic Wastewater Management In Bellbrae

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1. INTRODUCTORY COMMENTS

Bellbrae is a small town located 25km south-west of Geelong and 7.5km west of Torquay. The town has mains electricity but no reticulated water, gas or sewage. It has a primary school, town hall and football oval, but no shops. Two census mesh blocks over the town indicate that on census night in 2006 there were 204 people living in 68 dwellings.[1] Other census areas for the town are too large to draw any meaningful understanding of the town's population. Bellbrae's present planning zones are shown in Map 1.

Discussions with Council officers indicate that sustainable development is a key concern of the review. The focus of this report is on the environmental aspect of sustainability. Its purpose is to give Council a strategic understanding of the extent to which the ability of blocks to deal with wastewater onsite may constrain or permit additional development in the town. Chapter 3 of this report also is intended to explain the scientific and technical issues relevant to successful on-site effluent management and should help to explain the background to Table 1 in Chapter 4.

Because land prices for residential development in the Bellbrae Township are high, any further development is likely to be based on "life style" decisions from professionals who may be able to work from home and are able to travel by car for shopping and other business purposes. The township is too small to provide significant employment to residents. "Life style" development may include residents having small vegetable gardens for private vegetable and fruit production. Therefore Council officers have indicated to us that some evaluation of the natural suitability of soil for such purposes is useful.

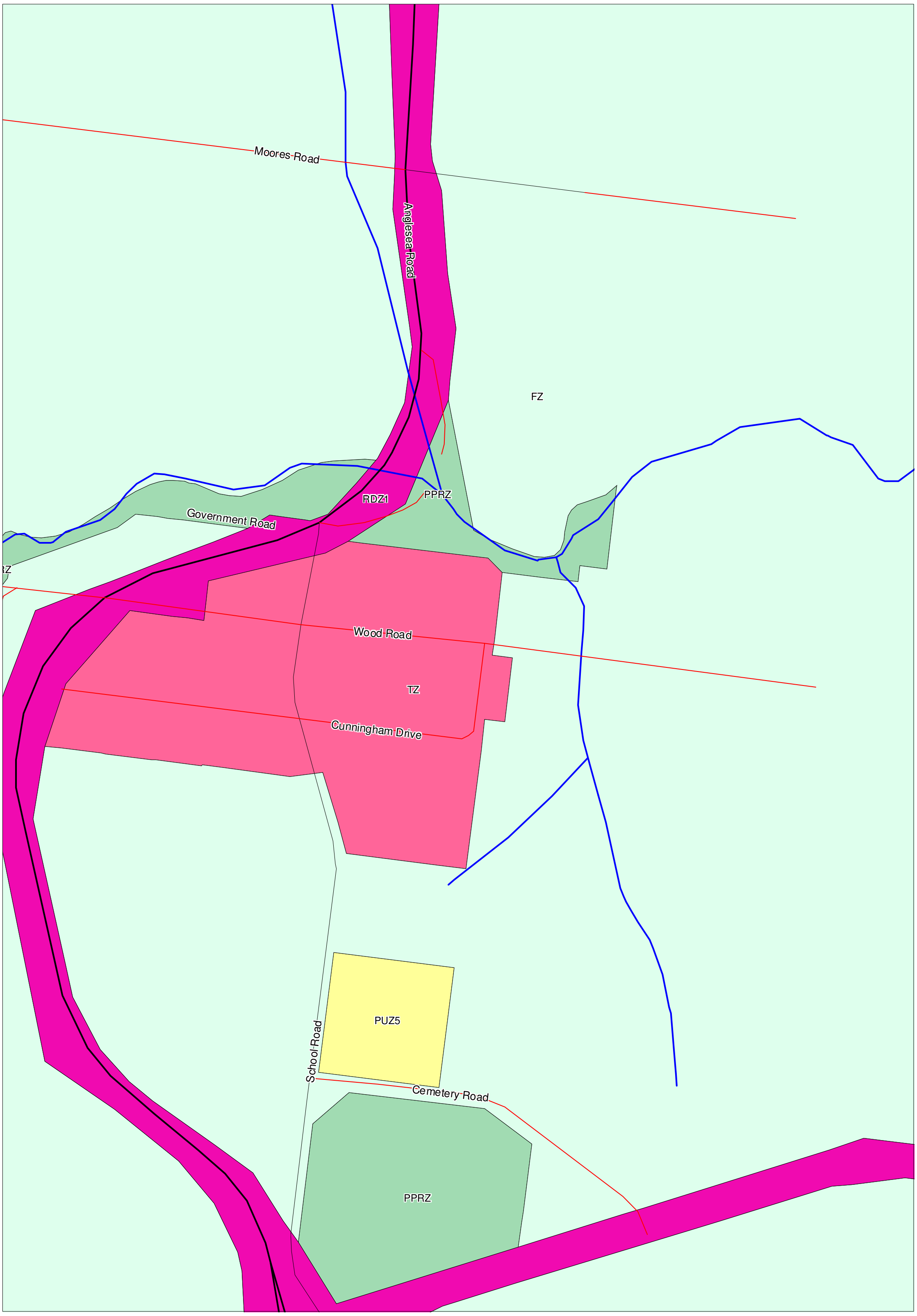
We recommend that the issuing of a building permit require a land capability assessment for the proposed development lot. We believe that it would be beneficial for assessors to be made aware of this report. This will facilitate the recognition of soil types they encounter and the properties of those soils that are important to on-site effluent management. In-situ determination of soil permeability must be done using the method specified in AS/NZS 1547:2000 to have validity.

This report therefore incorporates an extended Appendix containing explanations of the concepts and terminology relating to important aspects of soil science as they relate to onsite domestic wastewater management.

2. LANDFORMS AND SOILS OF BELLBRAE

The following material is based upon a reconnaissance soil survey of the entire Bellbrae Township, using geological maps, large scale aerial photography combined with stereoscopic photo interpretation, and field work during which the soil profile in a number of locations was explored and described. Four soil samples were taken for chemical analyses. We have placed the soils, which appeared to be typical of distinct landscape elements, in the nearest appropriate categories used in the Australian Standard for On-site Domestic Wastewater Management (AS/NZS 1547:2000) to assist those who are familiar with that document.

[1] Australian Bureau of Statistics, 2008, CData 2006. Census night was 8/8/2006



Map 1: Bellbrae Planning zones.

The Standard allocates numbers to soil categories of increasing permeability, such that very sandy and highly permeable soils are listed in its Table 4.1.1 as Soil Category 1, the somewhat less permeable but still quite permeable sandy loams as Soil Category 2, and so on to the very low permeability medium and heavy clays as Soil Category 6. Obviously, the extremely permeable soils allow the effluent to percolate through towards the groundwater table at high velocity and allowing little final treatment in such soils. At the other extreme, effluent dispersed on heavy clay soils with very low permeability will infiltrate very slowly, residing in the soil for long times, but such soils enable only very low loading rates to be used, requiring very large areas to be used for dispersal. Soil categories 3 and 4 are like a "happy medium" as they keep the effluent retained long enough, producing better final treatment in the soil, and can be used at moderate loading rates so that effluent application areas do not need to be excessively large.

The area within Bellbrae Township consists of an ancient, dissected plateau which has a relatively hard cap rock of an ironstone-like material that overlies much softer marly limestone along mid slopes. Spring Creek as well as a few of its local unnamed ephemeral tributaries, flow through the township and have eroded a deep valley through this plateau, exposing the marly limestone on the flanks of the valley. The eroding cap rock has contributed ironstone detritus along its edge on the upper slopes. Soil wash (colluvium) has also covered the lower slopes of the landscape. Spring Creek has built up two river terraces along its course in the township. The upper terrace is a former flood plain which is no longer inundated during flooding of the creek, however, the contemporary flood plain consists of a narrow area adjacent to the creek, and it will be flood prone.

The soils reflect this landscape closely and can be understood as distinct zones along the topography from the cap rock to Spring Creek. Bellbrae's soils are shown in map 2 and map 3.

Zone A – Cap rock

On the plateau surface there is much ironstone rubble in the soil profile but in the subsoil one finds reddish brown coloured clay, strongly structured, and easily explored by tree roots to some depth of at least 1 m. Because of the hardness of the cap rock, the edges of the plateau are often shaped like little escarpments to an intermediate zone (Zone B). This escarpment is easily observed near the school and behind the buildings. Cap rock plateau areas are located around the sports ground east of School Road, mostly covered by woodland, and along the western part of Moore's Road, partly also covered by woodland, as well as in a small, isolated "island" of trees in a pasture west of the Belllbrae-Anglesea Road, at about the same latitude as the aforementioned sports ground. The preservation of woodland on this land form suggests the soil may generally not be arable.

With regard to on-site domestic effluent management, the soil in this zone has been allocated to AS/NZS 1547:2000 Soil Category 4 Moderately Structured[2].

Zone B – Intermediate zone

[2] It must be emphasized that the allocation of AS/NZS 1547:2000 Soil Categories to the Bellbrae soils is a subjective process because it is based on a visual inspection. The need for actual measurement of soil permeability in land capability assessments remains.

This zone is found on convex and planar slopes immediately below the little escarpments at the edge of the cap rock. It is covered with fragments of the cap rock over a clayey soil that formed from a sedimentary material that may have been marl, but has lost its lime by the weathering and leaching that created the ironstone cap rock and underlying, associated soil.

With regard to on-site domestic effluent management, the soil in this zone has been allocated to AS/NZS 1547:2000 Soil Category 4 Moderately Structured.

Zone C – Mid slopes on marly sediments
Down slope from the intermediate zone, on convex slopes, one finds the soils that have formed entirely from the marl. They are friable, highly structured black clay loams with masses of white and cream coloured free lime in the subsoil.

These soils have been allocated to AS/NZS 1547:2000 Soil Category 3 – 4 highly structured in the upper portion of the subsoil, but weaker structured in the lower subsoil.

Zone D – Lower planar and concave slopes on soil wash.
At the base of the slope, close to Spring Creek, the soils become brown, sometimes mottled heavy clays, which have a strong shrink-swell capacity and form many cracks when they dry out.

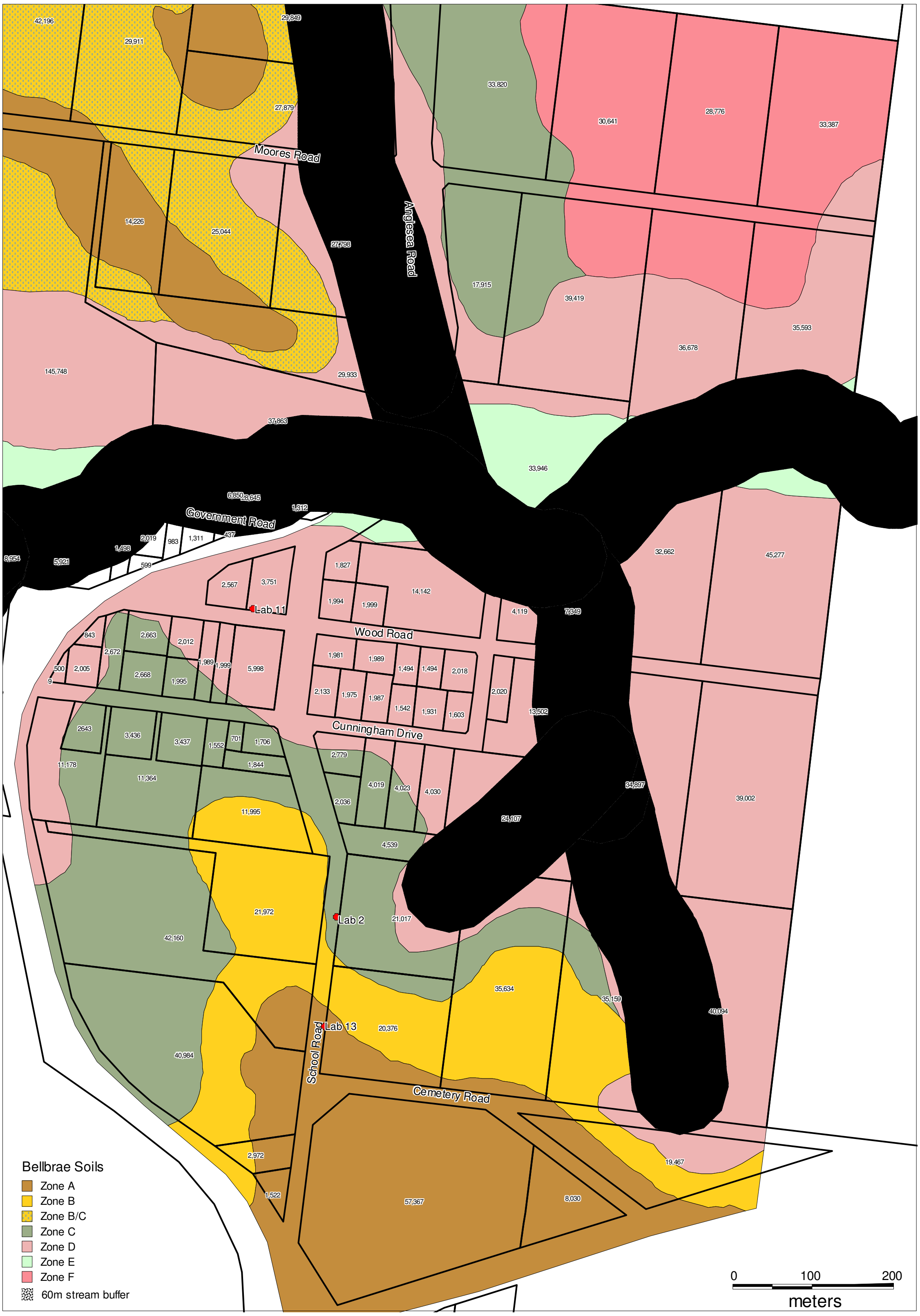
In terms of AS/NZS 1547:2000 these soils may be classed as Soil Category 5 Strongly structured.

Zone E – Alluvial terraces
The valley bottom possesses an older alluvial terrace which is now elevated above flood levels and locally has sandy soils that appear to have been blown out of the river bed during geological times when the creek did not flow continuously and its bed contained dry sand. A younger (contemporary) floodplain lies along the creek at lower elevation. It will be prone to inundation during high flows.

As the 60 m setback from open water bodies and drainage lines applies to on-site systems, most of the alluvial terrace land is not able to be utilised for future residential development. Small portions of the older alluvial terrace are outside the 60 m setback, the major one being at the foot of a steep hill slope where it could be subject to major runoff. Only a single soil profile observation was made for this terrace and it would be classed as Soil Category 4 moderately structured.

Zone F – Broad flat to convex hill crest area
On the opposite side of the valley the topography is similar to that on the Bellbrae township side, but the crest of the hill is composed entirely of a very heavy black cracking clay, which changes to black friable clay loams on marl very similar to those where the main township developed land is situated. Down slope from the crest and upper slopes the soil changes back to Zone C with soils formed on marly sediments.

In terms of AS/NZS 1547:2000 these soils may be classed as Soil Category 5 Strongly structured.



Map 2: Soil map superimposed with cadastre, 60 metre stream setback and sample points for soil sent for lab analysis. The area of cadastral blocks is shown in square metres.

Map 3: Aerial photograph, superimposed with stream setbacks, soil zones (A to F) and sample points for soil sent for lab analysis.

3. DESIRABLE SOIL PROPERTIES FOR ONSITE EFFLUENT MANAGEMENT

Onsite domestic effluent management is environmentally sustainable when the soils in which the effluent, either raw septic tank effluent or treated effluent, are reasonably permeable, with a stable favourable soil structure (see Appendix 1 for definition), and are dominated by exchangeable calcium in respect to exchangeable magnesium and sodium (See Appendix 1 for explanations). Soil permeability (this property is discussed in Appendix A) is a function of the interconnected network of pores and voids between compound soil particles, such as soil crumbs, in which individual soil particles are held together by humus, and natural soil units (peds) defined by intersecting cracks in the case of clayey soils that shrink and swell as the dry or wet up. Biological voids such as root channels, termite passages, etc., are also part of this structure. All such voids participate in the movement of water and air through a soil and therefore control the permeability.

The total depth of the soil profile is the next important property in relation to sustainable onsite effluent management. As the effluent slowly percolates through the soil, after it has been dispersed natural biological and chemical processes act to remove contaminants and faecal organisms. This process is time-dependent and hence if the path length through the soil is greater, the effluent resides longer in the soil and the renovation of the wastewater is better.

Other important soil properties include the level of natural organic matter and the clay content as a proportion of the total mineral soil. Where effluent is dispersed in shallow subsurface drip lines, soils with high organic matter will be superior to those with low organic matter, because the soil humus protects soil structure and promotes infiltration of water, as well as promoting plant growth and thereby plant water and nutrient uptake.

Soils with high clay content often have low permeability, although this depends on the quality of their structure.

Soil pH (acidity or alkalinity) plays an important role too, in that in acid soils (say pH < 6.0) phosphate from the effluent reacts with the soil's aluminium and/or iron to form very poorly soluble phosphates, thereby reducing the amount of phosphorus that can leach into the groundwater. The more acidic, the stronger this effect becomes. At much higher pH (say pH > 8.0) phosphorus reacts with the soil's calcium to form poorly soluble phosphates also.

Thus, a desirable soil for onsite effluent management should be deep, have good, stable structure and moderate permeability, be dominated by calcium in the cation exchange complex and have a high level of humus in the topsoil to promote vigorous vegetation growth.

At Bellbrae, the soils developed on the marly sediments are very rich in calcium and quite low in sodium and possess high levels of humus in the topsoil. The soils along the lower slopes and those underneath the cover of cap rock appear to be low in calcium and high in sodium and magnesium. This will be discussed in the next section.

4. CHEMICAL PROPERTIES OF THE MAIN SOIL TYPES

Table 1: Soil chemical analyses results

			Bellbrae Soil Wastewater Re-use Exploration				
Sample Name			Site 2	Site 2	Site 11	Site 13	
Soil Zone			Zone C - Marl		Zone D - Slope wash	Zone A - Weathered	
FILE NO :			091069361	091069362	091069363	091069364	
DEPTH OF SAMPLE (cm):			30-40	60-70	55-70	40-50	
AS 1547:2000 Soil Category - Allocated Classes			3 - highly structured	3 - weakly structured	5 - moderately structured	4 - moderately structured	
LAND USE :			Pasture	Pasture	Grassed nature strip	Grassed nature strip	
ITEMS			**RESULTS**	**RESULTS**	**RESULTS**	**RESULTS**	**DESIRABLE LEVEL**
pH(1:5 Water)			6.6	8.5	8.2	7.6	5.5-7.5
pH(1:5 0.01M $CaCl_2$)			6.1	8.1	7.8	7	
Electrical Conductivity	EC	µS/cm	292	252	219	334	< 300
TOTAL SOLUBLE SALT	TSS	ppm	963.6	831.6	722.7	1102.2	< 990
Water soluble Na		ppm	296	746	291	186	
Water soluble Ca		ppm	376	1304	435	17	
Water soluble Mg		ppm	311	260	607	13	
Water soluble K		ppm	504	349	818	22	
AVAILABLE SULPHUR	S	ppm	1.2	1.5	0.9	9.1	
TOTAL ORGANIC MATTER	OM	%	4.7	1.8	0.6	0.3	
EXCHANGEABLE CALCIUM	Ca	meq/100 of soil	28	19.54	10.9	3.58	
EXCHANGEABLE MAGNESIUM	Mg	meq/100 of soil	4.5	2.13	6.07	5.58	
EXCHANGEABLE SODIUM	Na	meq/100 of soil	1.8	1.09	2.48	1.83	
EXCHANGEABLE POTASSIUM	K	meq/100 of soil	1.65	0.31	0.29	0.73	
EXCHANGEABLE HYDROGEN	H	meq/100 of soil	9.6	0.01	5.8	8	
ADJ. EXCHANG. HYDROGEN	H	meq/100 of soil	7.25	0	5.5	7.85	
CATION EXCHANGE CAPACITY	CEC	meq/100 of soil	45.41	23.08	25.54	19.72	
ADJUSTED CEC	ACEC	meq/100 of soil	43.06	23.07	25.24	19.57	
EXCH. SODIUM PERCENTAGE	ESP	%	3.96	4.72	9.71	9.28	< 5
CALCIUM / MAGNESIUM RATIO	Ca/Mg		6.2	9.16	1.8	0.64	2 - 4
EXCHANGEABLE CALCIUM	Ca	*% of CEC*	61.35	84.66	42.68	18.15	
EXCHANGEABLE MAGNESIUM	Mg	*% of CEC*	9.91	9.23	23.77	28.30	
EXCHANGEABLE POTASSIUM	K	*% of CEC*	3.63	1.34	1.14	3.70	
EXCHANGEABLE HYDROGEN	H	*% of CEC*	15.97	0.00	21.53	39.81	
CHLORIDE	Cl	ppm	1139	567	463	403	
DISPERSION INDEX	DI	after 20 hours	0	0	10	10	
RECOMMENDATION							
GYPSUM REQUIREMENT		t/ha	0	0	8.3	5.6	
LIME REQUIREMENT		t/ha	0.1	0	0	0	
DOLOMITE REQUIREMENT		t/ha	0.7	0	0	0	
MAGNESIUM SULPHATE		kg/ha					
		KEY:	FAVORABLE	ACCEPTABLE	UNFAVORABLE		

Table 1 summarises all chemical data obtained from analysis of soil samples.

It is important to note that the results from these four soil samples are indicative only, but they do provide a general description of soil chemical character.

Note that the soil samples from the marly parent material in Zone C record very high calcium levels and have zero dispersion index. They also have a calcium/magnesium ratio of more than 4 and an exchangeable sodium percentage (ESP) of less than 6. These subsoil materials can be safely used for dispersal of domestic wastewater that contains normal levels of sodium, and no gypsum will be required.

The sample from site 13 characterises the soil directly below the cap rock in Zone A. The clayey subsoil here has lost much of its initial calcium and now exchangeable magnesium dominates exchangeable calcium and exchangeable sodium percentage is much greater than the standard threshold for safety of ESP = 6%. It is very slightly saline as well.

The sample from Site 11 represents the soils on the lower slopes. It is also too high in exchangeable magnesium and sodium and has a high dispersibility index. This means that when bare soil is exposed to water, the clay will disperse into the water and any runoff will be highly turbid.

In the Recommendations made by the laboratory both site 11 and site 13 soils (Zone B and Zone D) need to be amended with gypsum when used for onsite effluent dispersal. The rate of gypsum amendment varies between these two soils, but as gypsum is cheap and a higher rate of application cannot do any harm, it is recommended that all effluent dispersal areas be treated at the rate of 10 ton/hectare, or 1 kg/m^2. The gypsum may be applied to the bottom of any absorption trenches immediately after excavation and to the soil surface in the case of shallow subsurface irrigation.

5. HYDROLOGICAL CHARACTERISTICS OF THE MAIN SOIL TYPES

Zone A – Cap rock

These soils appear to be highly permeable in terms of strong structure but due to sodicity (ESP > 9%) may be less permeable than appears and they are believed to be best classed as AS/NZS 1547:2000 Soil Category 4. It is expected that onsite effluent dispersal would not pose problems here.

Zone B – Intermediate zone

These soils have mottled clay subsoils and would appear to be of lower permeability than the Zone A soils that lie directly above them in the landscape. The fact that they are probably also somewhat sodic (ESP > 6%) suggests that they can become even less permeable if used for effluent dispersal without gypsum treatment of the soil. No samples have been collected from this area for laboratory analysis.

Zone C – Mid slopes on marly sediments
The black marly clay loam soils here have highly developed structure and high levels of organic matter extending well down the profile. They are assessed as moderate to low permeability and would require somewhat smaller effluent disposal fields per unit volume of effluent dispersal than is the case for soils in Zone B and Zone D.

Zone D – Lower planar and concave slopes on soil wash.
The mottled soils of the lower slopes of Zone D are likely to have low to very low permeabilities. These soils are dispersive and hence care must be taken to prevent or minimise erosion when any soil excavation activities are conducted.

Zone E – Alluvial terraces
Flood prone.

Zone F – Broad flat to convex hill crest area
Zone F has black cracking clay soils and is expected to have the lowest permeability of all Bellbrae soils.

6. AGRICULTURAL AND HORTICULTURAL SOIL QUALITY

The aspect of self sustainability for food production has been raised by Council. From this perspective the friable black clay loams of Zone C would be very productive for stone fruit, most probably for apricots and peaches. They have a great depth of soil available for root penetration, as roots can also penetrate the marly material below the soil profile proper. The large amount of calcium in these soils would be beneficial to fruit trees, and also to olives. They probably also have a high water holding capacity.

The evident high level of organic matter in the topsoil also renders them favourable for home vegetable gardens.

However, it is believed that the soils in Zones B and D can also be productive.

7. EFFLUENT DISPERSAL FIELD SIZING

Tables 2 and 3 present the recommended areas for irrigation systems and the modelled space requirements for a lot accommodating a 4-bedroom house, driveway and any sheds, as well as the effluent dispersal area, including setbacks. We base our discussion on a four bedroom home because we believe that to be the most likely development scenario. The modelling assumes that all houses will have 450 m^2 of impervious areas and that the irrigation areas are squares. For any specific residential development proposal the consultant or land capability assessor needs to work out the precise space requirements and lay out, as no two houses will have exactly similar foot prints.

Absorption trenches are not considered to be best practice in situations where the effluent can also be treated to secondary quality and irrigated so as to create a beneficial resource for garden watering.

The daily flow rates are in accord with the most recent Code of Practice and the currently proposed values of 140 L/person.day.

Table 2 Irrigation field sizing

Formula: Daily Volume = # BR + 1) x 140 L										
Flow per person/day		**140**								
Landform-Soil Zone										
Soil Category (AS/NZS 1547:2000)										
Effluent (L/day)										
1 bedroom	280									
2 bedrooms	420									
3 bedrooms	560									
4 bedrooms	700									
5 bedrooms	840									
			Zone C			***Zone A***			***Zone D***	
Landform-Soil Zone			***Zone E***			***Zone B***			***Zone F***	
Soil Category (AS/NZS 1547:2000)			*3*			*4*			*5*	
Effluent loading (mm/day)			*28*			*25*			*20*	
Effluent loading (L/day)			***4***			***3.6***			***2.9***	
			Irrigation area required (m2) without envelope							
1 bedroom	280		70.0			78.4			98.0	
2 bedrooms	420		105.0			117.6			147.0	
3 bedrooms	560		140.0			156.8			196.0	
4 bedrooms	700		175.0			196.0			245.0	
5 bedrooms	840		210.0			235.2			294.0	
			Suggested layout as compact square dispersal areas							
			length	**width**		**length**	**width**		**length**	**width**
1 bedroom	280		8.4	8.4		8.9	8.9		9.9	9.9
2 bedrooms	420		10.2	10.2		10.8	10.8		12.1	12.1
3 bedrooms	560		11.8	11.8		12.5	12.5		14.0	14.0
4 bedrooms	700		13.2	13.2		14.0	14.0		15.7	15.7
5 bedrooms	840		14.5	14.5		15.3	15.3		17.1	17.1

8. RECOMMENDATIONS

The purpose of this section is to provide recommendations as to which areas in Bellbrae further development would be environmentally sustainable.

Those factors that contribute to the size of an effluent disposal area are most important in Bellbrae and they will differ between blocks on the basis of dwelling size and the ability of each soil type and technology combination to deal with wastewater onsite. Because the mapping of the various soil units cannot be definitive on an individual allotment basis, it is recommended that specific development proposals should be supported by an LCA, accompanied by soil testing – permeability as well as basic chemical (pH, EC and ESP) - informed by this report and include an estimated water balance for the LAA.

Prospective land capability assessors should be provided with access to this report to enable them to appreciate the specific soil factors we have identified in this area. This implies also that applicants for septic tank permits should be made aware that this report can be made available to their consultants.

It is also recommended that Council adopts procedures to ensure that on-site systems are maintained according to their manufacturer's recommendations.

For the purpose of this document we have assumed that future development in Bellbrae would most likely be 4 bedroom dwellings with an impervious surface footprint (house, outsheds and paved areas) of 450m^2. Table 3 summarizes information contained in Table 2 and table 3 as it relates to a 4 bedroom home.

Flow rates for public and commercial premises are presented in Table 5.

Table 3: Irrigation system disposal area requirements for a 4 bedroom dwelling in each soil zone. The impervious surface allowance is a nominal figure chosen to represent roofs, paths, driveways, etc. that are normally associated with rural type developments. This figure will undoubtedly vary from site to site.

Soil zone	AS/NZS code	Beds	Field size m^2	+ impervious surface allowance	= total area requirem't m^2	+ Allowance for setbacks m^2
C and E	2B and 3A	4	175	450	625	195
A and B	4B	4	196	450	646	204
D and F	5B	4	245	450	695	224

Table 3 needs to be read in association with Table 2. The allowance for setbacks has been calculated assuming the effluent irrigation fields are exact squares and surrounded by a 3 m setback all around. It is evident that for these modelled idealised effluent field sizes plus setbacks, the minimum lot sizes will be not much smaller than 1000 m^2. Thus it is incumbent upon the developer to maximise the efficiency of the layout of the house and driveway to enable the effluent field to be spatially unconstrained and for stormwater and runoff to be diverted from it. An effluent field must be part and parcel of the entire design of the house and its surrounding garden. This report assumes that lot sizes should be a minimum of 1000 m^2. This size also favours an appearance of the area as small town.

Presently Bellbrae is characterized by large town blocks, mostly in the order of 1000 m^2, 2000 m^2, 3000 m^2 and 4000 m^2 (¼, ½, ¾ and 1 acre). A number of blocks on the town periphery exceed 10,000 m^2. In map 2, each block is annotated with its area (as m^2) and overlaid onto the soil zones. Read in conjunction with table 4, opportunities for future development can be seen.

The potential for cumulative impacts of onsite systems should always be kept in mind when undertaking strategic town plans. In table 4 we suggest block sizes that would be sustainable in the long term. However, in terms of the potential for cumulative impact, these suggestions should be cross referenced against the soil map. In general terms map 2 is shaded such that green shades represent soils most suited, yellow shades moderately suited and red shades, least suited for high density development using onsite wastewater systems.

The calculations we show in Table 2 and Table 3 are for irrigation systems. Irrigation systems are considered best practice in the latest draft Code of Practice, so we therefore cannot recommend trench systems.

Table 4: Summary of recommendations

Soil zone	AS/NZS category	Recommendation	Comments	Soil improvement of dispersal fields
A	4	Lots exceeding 1,000 m^2	Ironstone fragments may make subsurface drip line installation difficult.	Incorporate gypsum before or apply at surface after installation
B	4	Lots exceeding 1,000 m^2		Incorporate gypsum before or apply at surface after installation
C	3-4	Lots exceeding 1,000 m^2	Along Moore's road, steep with irregular slope shapes restricting freedom of lot layout, access and house positioning.	Where masses of whitish soft lime can be seen in the subsoil, gypsum is not required
D	5	Lots exceeding 1,000 m^2		Incorporate gypsum before or apply at surface after installation
E	n/a	n/a	Subject to flooding and constrained by 60m stream buffer.	Incorporate gypsum before or apply at surface after installation
F	5	Lots exceeding 4,000 m^2	Not well suited to higher development densities.	Incorporate gypsum before or apply at surface after installation

Improve soil of dispersal area by incorporating gypsum during the cultivation prior to installation of the subsurface irrigation lines, or apply after installation as a dusting over the surface. An application rate of 8 tonne/hectare is equivalent to 0.8 kg/m^2.

Table 5: Wastewater flow rates. Source: Draft EPA Code of Practice – Onsite Wastewater Management (Publication 891.3), January 2010.

Water Source	Typical wastewater flow rates[1,2] (L/person/day)	
	On-site roof water tank supply only	**Reticulated community or bore-water supply or river water supply**
Households with extra wastewater producing facilities	170	220
Households with standard water fixtures	140	180
Households with water-reduction fixtures [3, 4]	120	150
Households (blackwater only)	25%	30%
Households (greywater only)	75%	70%
Motels/hotels — guests, resident staff — non-resident staff — reception rooms — bar trade (per customer) — restaurant (per diner)	 140 30 20 20 20	 180 40 30 25 30
Community halls — banqueting — meetings	 20 10	 30 15
Restaurants (per diner) — dinner — lunch	 20 15	 30 25
Tea rooms (per customer) — without restroom facilities — with restroom facilities	 10 15	 15 25
School (pupils plus staff) Rural factories, shopping centres	30 30	40 50
Camping grounds — fully serviced — recreation areas	 100 50	 130 65

KEY:

1. Based on AS/NZS 1547:2000 (page 141).
2. When calculating the flow rate for a premise, use this table or local data that is scientifically and statistically significant i.e. metered water usage data, for indoor use only, from the local Water Corporation.
3. These flows are minimum rates unless actual flows from past experience can be verified.
4. Water-reduction fixtures and fittings include dual-flush 11/5.5 litre or 6/3 litre water-based toilets, shower-flow restrictors, aerator taps, flow/pressure control valves and water-conserving automatic washing machines.

The size of a dispersal area for any specified type of soil is proportional to the volume of wastewater to be dispersed. In Table 2 it is shown that a 4-bedroom house has been assumed to generate 700 L/day requiring a dispersal area of 175 m^2 on soil zone C and E. Therefore, a proposed hotel generating, say, 1400 L/day would require (1400/700) x 175 m^2 = 350 m^2 of dispersal land.

APPENDIX 1

EXPLANATIONS OF SOIL SCIENCE AND OTHER TECHNICAL TERMINOLOGY

A1 – Cation exchange and exchangeable cations

All soils possess a so called cation exchange capacity (CEC), meaning that clay particles and humus particles can adsorb positively charged ions like calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), aluminium (Al^{3+}) and hydrogen (H^{+}) because the clay and humus have in-built negative charges. Thus the soil is electrically neutral as the total amount of positive charges is exactly balanced by the total of negative charges. The greater the proportion of clay and of humus in the soil, the greater is the soil's CEC. The adsorbed cations are held in exchangeable form, meaning that, if some Ca^{2+} is removed from the CEC, the loss of positively charged cations must be compensated by other positively charged cations, for example Mg^{2+} and/or Na^{+} etc. so that the clay and humus remain electrically neutral. This is illustrated in figure 1.

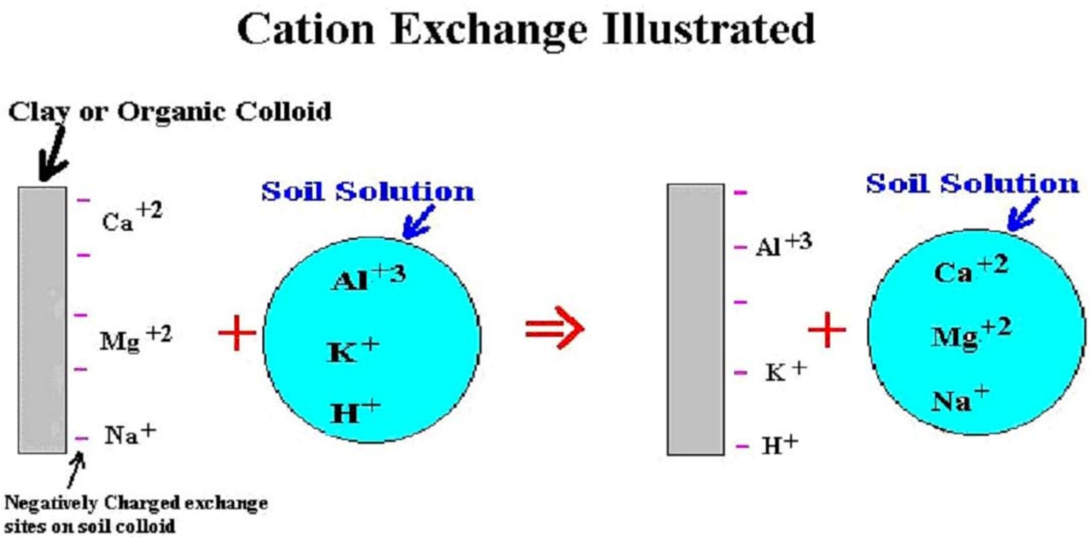


Figure 1: Cation Exchange Capacity (CEC)

Soils that are dominated by exchangeable calcium tend to have stable structure because their clay particles stick together (i.e. are flocculated), but when exchangeable sodium and/or exchangeable magnesium become more important than the calcium, the clay component of the soil tends to become dispersive. When dispersive clay becomes wet or saturated with water the individual clay particles separate from the compound particles.

The flocculation or dispersion of clay particles is illustrated in figure 2.[3]

When the clays are dispersed, the individual particles are suspended in water and are too small to settle under gravity and then tend to be dragged down into the pores with the percolating water blocking them (figure 3).

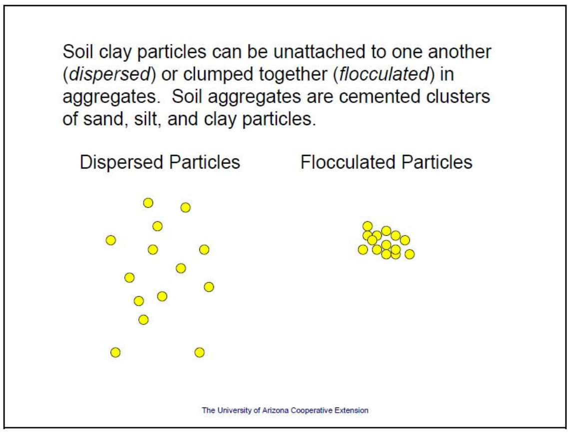


Figure 2: Flocculation and dispersal of clay particles (Walworth, 2006)

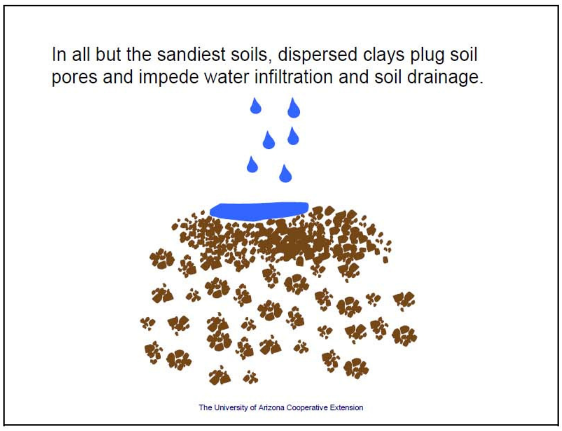


Figure 3: Dispersed clays.(Walworth, 2006)

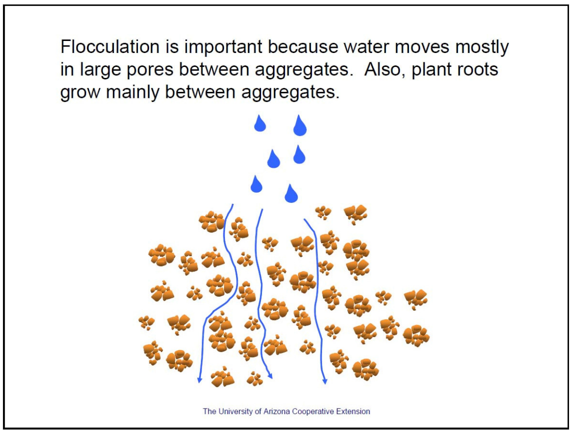


Figure 4: Movement of soil and air through a soil (Walworth, 2006)

Clearly, if the soils are flocculated and consist of collections of flocculated particle domains, the void spaces between the domains will consist of larger compound units and hence facilitate the movement of water and air (Figure 4).

Many Australian soils naturally have higher levels of exchangeable sodium and magnesium than of exchangeable calcium. Thus they are prone to dispersion when disturbed, as by digging absorption trenches or cultivation and then being suddenly exposed to water from effluent or rainfall. Because domestic effluent tends to have an imbalance in favour of sodium compared to calcium, the tendency towards dispersion in increased further. However, by amending these soils with gypsum, calcium sulphate ($CaSO_4.2H_2O$) the imbalance can be counteracted and the soil

[3] The diagrams in figures 2 thru 4 were produced by Dr. Jim Walworth, Department of Soil, Water and Environmental Science, University of Arizona, as a part of a PowerPoint presentation titled “Soil Structure: The roles of sodium and salts” (2006).

structure and soil permeability protected. Figure 5 shows that calcium has by far the greatest flocculating effect of the four common cations on a soil's exchange complex.

Ion		Relative Flocculating Power
Sodium	Na^+	1.0
Potassium	K^+	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

Figure 5: Calcium has by far the greatest flocculating effect of the four common cations on a soil's exchange complex (Walworth, 2006).

A2 – Permeability (hydraulic conductivity)

Saturated soils

The permeability of a soil is a measure of how rapidly water can move through it under a driving force of specified magnitude. If a soil is saturated, the driving force is the force of gravity and the movement will be vertically downwards if there is no barrier to that movement. In an aquifer there is always an impermeable bottom or much less permeable base causing the water to flow sideways to a lower area, e.g. towards a river channel in a valley. The driving force is still gravity, but the gravity force is then split in a small lateral, down slope force and a remaining vertical component. We speak of a hydraulic gradient and it is equal to the slope angle in % of the fall of the impermeable base.

For example, if groundwater in an aquifer moves towards a river channel over a slope of 2% (2 m fall in 100 m horizontal distance) the hydraulic gradient is 2%. If the permeability of the saturated sand or gravel, Ksat, in the aquifer is 5 m/day, then the lateral seepage velocity, V, is, according to Darcy's Law:

$$V = (2/100) \times 5 \text{ m/day} = 0.1 \text{ m/day}$$

To traverse a distance of 1 km to the river, a drop of water would take:

$$1000 \text{ m} / 0.1\text{m/day} = 10{,}000 \text{ days or more than 27 years.}$$

Unsaturated soils

In unsaturated soils, the water can only move through any pores that are small enough to be filled with water. Thus, the permeability of unsaturated soil, Kunsat, depends on the degree of unsaturation. The drier the soil, the more that the water is restricted to ever smaller and narrower pores and the more sluggish its movement. Therefore, to promote good treatment of effluent in the soil one should maximise the residence time of effluent in the soil and hence minimise overloading and saturation.

Soil permeability testing by the method specified in AS/NZS 1547:2000 provides data on Ksat. However, the recommended loading rates in that Standard are very much lower than the measured Ksat in order to ensure that effluent dispersal cannot cause saturation (waterlogging) of the application area.

A3 – Soil structure and grade of structure

Soil structure describes the arrangement of the solid parts of the soil and the pores spaces located between them. It depends on what the soil developed from and the environmental conditions under which the soil formed as well as the clay and organic matter that may be present.

In sands the individual sand grains usually are jumbled together such as to be less dense than is theoretically possible with a maximum dense packing, and are considered to have no structure, like a bucketful of haphazardly arranged marbles. If all sand grains are much the same size, the amount of void space between is maximal. If the sand soil consists of sand grains of a variety of sizes, the smaller grains can fill up the voids between the larger grains, so that the total void space per unit volume of sand is less than it is with uniform sized grains.

In clay soils, the clay usually has the ability to shrink and swell under drying and wetting and so can develop much larger compound units separated from each other by drying cracks which tend to become permanent planes of weakness. Some kinds of clay minerals do this to a very high degree.

The degree to which these natural compound soil units are formed and their distinctness of shape and size is a measure of the "grade" of structure. This kind of soil structure is a **macroscopically visible structure**. The permeability of many soils is much more affected by the microscopically observable structure, mainly the product of biological life in the soil, which is not assessed by AS/NZS 1547:2000.

Grade of structure is used as a very rough indicator of the relative permeability of soils by AS/NZS 1547:2000. The Standard allocates "Indicative" permeability values to soils of varying textures and grades of structure. It then proceeds by recommending indicative loading rates so that the soil that is rated to be the most permeable can also receive the highest loading rate and those soils suspected of having very low permeabilities are loaded at the lowest rate. It should not be forgotten that these visual ratings ought to be quantified by actual site testing, but AS/NZS 1547:2000 does not make such tests mandatory. It must also not be forgotten that the loading rates are wholly based on hydraulic soil properties and do not at all consider the retention of nutrients, chemical and microbiological and other household contaminants by the soil, or the uptake of nutrients and water by the vegetation on the dispersal field.

The Standard particularly advocates a higher standard of effluent treatment for the most troublesome, low permeability soils, Category 6, including "special design", because secondary class treated effluent can be infiltrated in such soils more readily without creating biological slimes on the receiving soil surface that could act as an additional barrier.

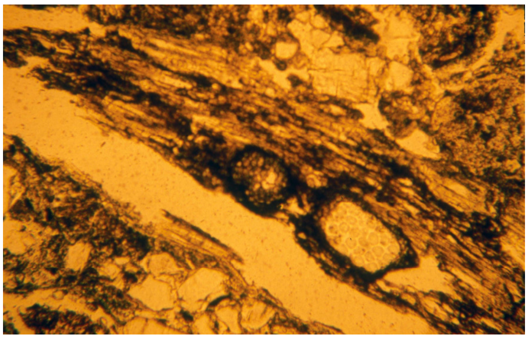
Obviously, if a soil is made up of clay, but the clay is highly organised ("strong structure") into large ("coarse"), loosely fitting compound units, the voids between these units will be large too and the soil may be assumed to be very permeable. This expectation breaks down when the clay soil is a highly swelling one, so that when it is wet it may be almost impermeable. A clay soil that is not so highly organised into compound units, but is little subject to swelling and shrinking and has a well developed biological life, may be moderately permeable both when dry and wet.

However, the criteria used in the Standard may serve as a first estimation of hydrological soil properties, with on-site actual field tests providing more reliable data for sizing and design.

Structureless topsoil over strongly angular blocky structured clay subsoil – macroscopic assessment (scale: pocket knife)

Strongly structured clay subsoil, prismatic and breaking apart in coarse angular blocks – macroscopic assessment

Termite channel in soil with its walls strengthened with organic exudates – microscopic view



Root channel with decomposing root and organic matter linings maintaining the pore – microscopic view