ON EFFLUENT INFILTRATION IN SPITE OF WATERLOGGING

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Abstract

Seasonal intermittent waterlogging of an on-site effluent disposal field is persistently, but often wrongly, equated with failure. The view that if the soil is "full of water" then it is not possible to add more water is too simple and static an analysis. This misapprehension leads to an excessive emphasis on determining the maximum height of the perched water table in a soil, in order to rate the potential of that soil for effluent disposal. It leads to further error by the consequent notion that the measurement of soil permeability ought to be done at that time when the soil is at its most waterlogged, which is precisely the condition when such a measurement can only produce an invalid result.

As our field observations show, even while a soil is suffering from seasonal intermittent waterlogging, effluent "absorption" is still taking place. In addition, the storage capacity of the trench (different per trench type) can help tide over periods of slow absorption. We have quantified these effects and incorporated them into a series of equations for sizing domestic septic tank effluent disposal fields, presented in this paper. The method can also take account of main infiltrative surfaces (trench bottom, sidewall or both); runoff; any evapotranspiration of effluent by vegetation directly over the trench; and evapotranspiration by vegetation in a border zone adjacent to the trench (zone width dependent on vegetation type). We also discuss the logical inconsistency of the argument that soil permeability needs to be tested when soils are at their wettest. We conclude that, in judging the potential of an area for effluent disposal, the duration and severity of seasonal intermittent waterlogging should be assessed from soil profile characteristics and/or hydrological monitoring. Permeability tests, on the other hand, should be used exclusively for determining soil permeability as a step in sizing effluent disposal systems, and not for assessing soil water regimes.

Keywords

Intermittent seasonal waterlogging, septic tank effluent absorption failure, permeability testing, domestic wastewater, Melbourne, Victoria, Australia

1 Introduction

Throughout the moderate to high rainfall (>600 mm per annum) regions of Australia, intermittent and seasonal waterlogging in the upper parts of soil profiles is a common condition, particularly during the wetter and/or colder season. In these regions soil types having lower permeability in the subsoil than in the topsoil are widespread, probably even dominant. Such soils usually show an increase in clay content with depth, but they may also be of uniform texture. Waterlogging in the upper parts of such soils will occur when, over a nominated time interval:

(rainfall + surface runon) – (runoff + evapotranspiration) > (available soil water storage + vertical and lateral drainage)

Many environmental health officers in local and State governments labour under the misapprehension that any intermittent saturation of the soil, within, say, the upper 1.2 m of the soil, dooms on-site effluent disposal systems to failure. They believe that no intermittent saturation should occur within, say, the upper 1.5 m for the soil to be fully suitable for effluent disposal. They appear to base this on the assumptions that during soil saturation:

- all vertical (and lateral) drainage below the application surface as well as below the surrounding land ceases;
- the hydraulic gradient within the absorption trench or bed is reversed upwards; and
- the absorption trench itself has no capacity to temporarily store more effluent.

It is then logical for the same people to conclude that measurement of soil permeability (or of soil percolation rate[1]) should be carried out when the soil is in its most saturated condition.

As we demonstrate below, these ideas have taken firm root in septic tank regulations, in land capability rating tables and in the practices of many consultants on effluent disposal. However, in this paper we also present field data that show that the above assumptions and conclusions are often incorrect. Downward and lateral drainage and effluent absorption regularly continue under waterlogged conditions, faster even than when the soil is drier. Also, the storage capacity of the trenches can help effluent disposal fields to keep functioning during particularly wet periods. We show how all this can be included in an effluent disposal field sizing method. The method was developed following monitoring of thirteen disposal fields under a range of conditions in the greater Melbourne area. From the field data, as well as elementary physics, it also follows that soil permeability testing, necessary for disposal field sizing, should never take place under waterlogged conditions.

2 Wrong Assumptions and Confusion in Effluent Disposal

2.1 A seasonal water table, groundwater, impervious layer – are they all the same?

The confusion about temporary waterlogging is well exemplified by the Victorian Code of Practice – Septic Tanks (EPA 1996), although there is similar confusion elsewhere. Appendix A, which deals with land assessment for effluent disposal, correctly states (p. 37):

"Features which may influence a soil's capability to absorb and purify septic tank effluent or affect the ease of installation of septic tank systems include:
- wetness of the site – as expressed by the duration of waterlogging on small, localised areas which are part of larger, naturally draining, sloping upland areas or by the depth to a seasonal high water table for flat areas".

The above quote is an almost verbatim copy of the relevant paragraphs in its predecessor, the 1990 Code (EPA 1990), intended there as a general warning. It also distinguishes between naturally draining "sloping uplands and flat areas", called "*flat basins and plains*" in the 1990 Code. The 1990 Code recognised that the movements of water tables in basins and plains – often true water tables - tends to be very much slower than in sloping uplands – often perched water tables - and hence made this vital distinction. The 1996 paraphrasing suggests the recognition has been lost. Continuing on the same page of the 1996 Code, the new checklist for land assessment quantifies the depth to *"groundwater"* as having to be greater than1.5m.

The land capability rating table on page 39 of the 1996 Code adds to the confusion of terms by stating:

	Land features affecting use	*Capable (1)*	*Marginal (2)*	*Not capable (3)*
D	*Depth to seasonal water or impervious layer (first water)*	*> 1.5 m*	*1.5-1.2 m*	*<1.2 m*

The term *"first water"* suggests that a perched water table is included with a true water table. Similarly, the aspects of duration of waterlogging in freely draining upland sites and slowly moving groundwater tables in basins and plains have fused into the same vague idea of something that is too wet to be of any

[1] The so-called soil percolation rate is a raw entity, which incorporates soil permeability, as well as elements of the test procedure such as the geometry of the test hole, height of initial water level, and time interval between recording water levels in the hole. If these elements are known, a value for soil permeability may be calculated.

use. Also, when a layer must be classed as impervious is not defined, nor is the term *"first water"*.

To make matters worse, the 1996 Code, Table 1.1 on page 7 presents guidelines for effluent disposal options using different values for depth to water tables and seemingly excluding a true ground water table, while the presence of rock (any rock?) can substitute for the water table:

Factors affecting suitability for on-site disposal	*Generally suitable, subject to other criteria being met*	*May be suitable, subject to investigation and/or design*	*Generally not suitable*
Depth to winter/spring water table or rock	*>1.5 m*	*0.75-1.5 m*	*<0.75 m*

Appendix B of the 1996 Code in relation to the soil percolation test specifies that the test *"may be performed at any time of the year as long as the water table is more than 1.5 m from the surface"*. The next sentence then appears to negate the preceding one by recommending that *"The proposed disposal site should be inspected at the wettest time of the year to ensure the water table does not rise within 1.5 m of the natural ground surface."* And all of this is without any of these criteria having a documented experimental basis!

2.2 Site assessors' confusion

This confusion and lack of understanding of the physics of soil water in official guidelines is mirrored by wrong conclusions and wrong advice offered by consultants, and both are inimical to good environmental management. In June 1996 a major consulting firm did percolation tests in a northern outer Melbourne Shire to assist that Shire in developing a land planning strategy and classify land that could be developed for on-site effluent disposal as opposed to land that should be sewered. The consultant reported (we quote) *"apparent undesirable percolation results"* which were "*in contrast to regional experience",* because *"it is understood that septic tank systems have been operating in generally similar soil profiles as that encountered on the site"*. The geological engineer in charge of the work reported that *"free groundwater was not observed in any of the bores, however distinct wet horizons were encountered in bores 3, 8 and 13."* The same report states that several days later *"water levels in all test holes, except site 6, had risen to the ground surface"*. A year earlier that same firm had expressed some surprise that percolation rates in the same area, measured in the same season for a different client, were so low.

Later, in October 1996, in relation to a proposed subdivision near Inverloch, yet another firm, priding itself on its Corporate Membership of a professional society, reports that its test holes *"were observed to be in a very damp to saturated condition"*. Nevertheless, the tester found it necessary to pre-soak the holes for 20 hours before starting the percolation tests, concluding *"our results should be considered as representative for the area"* and promising a bleak outlook for septic systems. If the soils weren't already 100% saturated, the pre-soaking would have done it. That Darcy's Law is identical in form to Ohm's Law seems to have escaped these engineers. What they were trying to do is tantamount to measuring electrical conductivity in a copper wire by first shorting out their battery until it was totally dead and then concluding that copper does not conduct electricity.

Both consultants attempted to carry out a test which is designed as an "*above* the water table" method for determining soil permeability. However, they did this under conditions equivalent to being *below* the water table. To his credit, the first consultant took the trouble to consult with the environmental health officer of the Shire and hence was in a quandary to explain the apparent contradictions between test results and known performance of disposal fields. The second consultant applied the confused concepts of the Code in a wholly uncritical manner and praised it as being *"state of the art"*.

3 Effect of Intermittent Seasonal Waterlogging on Effluent Disposal

3.1 Introduction

The experience of the consultant in the Shire on the northern periphery of Melbourne illustrates that satisfactory performance may be the rule even when the soil suffers from intermittent saturation in winter.

Local anecdotal knowledge, critically obtained, is indeed extremely valuable in evaluating and extending theoretical insights and experimental data. But scientific field studies also have an important role to play.

Brouwer and colleagues (Brouwer 1982, Brouwer *et al*. 1979, Brouwer and Bugeja 1983) studied the performance of thirteen septic tank effluent disposal fields around the eastern and northern outer suburbs of Melbourne, and further west as far as Lara and Bacchus Marsh, in relation to local soil type, climate and effluent loading. In this paper we concentrate on the results from their site at North Whittlesea, 40 km north of Melbourne and about 2.5 km west of Kinglake West on the Kinglake Plateau, at an altitude of about 450m.

3.2 Physical site characteristics of the North Whittlesea effluent disposal field

The effluent disposal trenches were constructed in an acid, massive yellow earth with a bleached A2 and mottled B horizon (Gn 2.74), formed on Silurian-Devonian silt and mudstone, on a slope of 6-7%. Bedrock was more than 2 m deep. Hydraulic conductivity of the B2-horizon, measured at 0.25-0.55 m depth, gave a geometric mean of 8 mm/day in the surrounding lawn (6 tests) and 2 mm/day in an adjacent grass and bracken field (12 tests). The constant head well permeameter method of Talsma and Hallam (1980) was used for these measurements. The site was characterised by a periodic perched water table on top of the B2-horizon, sometimes reaching almost to the surface.

The septic tank and absorption trenches received only effluent from the toilet, but the household was entirely dependent on rainwater, so that measured daily water use in the toilets varied between only 44-62 L/day in 1978, increasing to 68 L/day in 1979. Initially there were only two parallel 9 m long trenches (dating to pre-1965), which were replaced by one 18 m long new trench in October 1978 as the house was being extended. All sullage was discharged off-site.

The general area has high rainfall, P; some 1200 mm per year is recorded at the nearest long term recording station of Kinglake (64 years; Met. Station # 086061). The rainfall at North Whittlesea is probably slightly less than this. The nearest location for pan evaporation, Eo, is Yan Yean Reservoir (altitude 198 m; Met. Station # 086131) but its evaporation rates are probably somewhat higher than they would be for North Whittlesea, for which location there are no data. The values for evapo-transpiration, Et, shown below, have been calculated using a crop factor of 0.75. It will be clear from Table 1 that North Whittlesea is a relatively wet location, particularly in winter.

Table 1. Approximate long-term climatic data for North Whittlesea (in mm per month or year)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Eo	195	167	128	80	49	32	40	55	78	111	137	180	1252
Et	146	125	96	60	37	24	30	41	59	83	103	135	939
P	73	76	83	101	107	111	111	115	111	118	105	98	1209
Water deficit	73	49	13	-	-	-	-	-	-	-	-	37	172
Water excess	-	-	-	41	70	87	81	74	52	35	2	-	442

3.3 Instrumentation and monitoring

Observations to assess effluent absorption were made almost daily from July to November 1978, but this was reduced to about two to three times per week for six weeks thereafter. From June 1979 till the middle of October 1979 the frequency of monitoring was again two to three times per week.

An electronic counter was placed in each of the two toilet cisterns to count the number of flushes each day. A rain gauge on site provided daily rainfall data, and background rainfall data were obtained from the Bureau of Meteorology. The old absorption trenches were instrumented with a standpipe in the trench and 12 tensiometers in and around each trench section. When the new trench was put into service, two standpipes and 26 tensiometers were placed in and around it. Typical standpipe and tensiometer positions are shown in Figure 1.

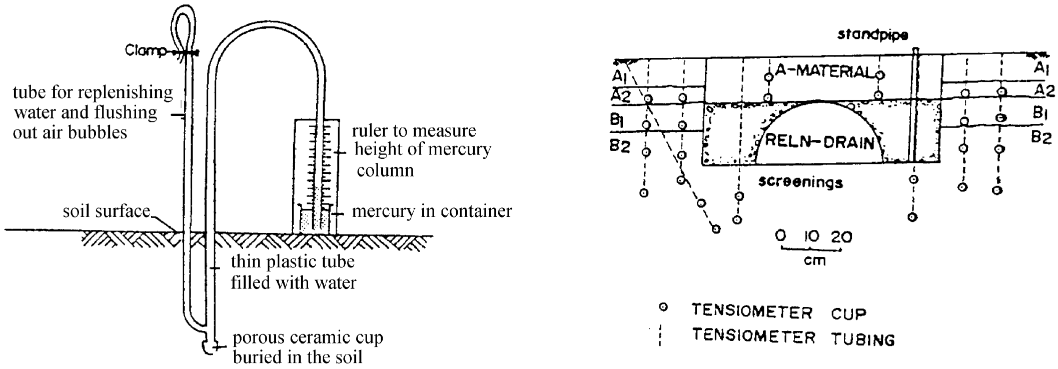


Figure 1 Diagram of the tensiometer principle and tensiometer positions around a trench at North Whittlesea.

The standpipes provided data on the ponding level of effluent in the trench. From this and the data on effluent outflow from the toilets, it is possible to estimate the wetted area in the trenches and the average rate of effluent infiltration per m of trench. The tensiometer data allow calculation of iso-potential lines and thus provide information on the main direction of infiltration: water movement is at right angles to these lines. Where the infiltration takes place at a lesser rate, the soil becomes dry more quickly with distance from the wetted trench wall or bottom surface, the matric potential gradient will be steeper and iso-potential lines in a vertical cross section through the trench system will be bunched closer together. From the tensiometer data it can thus be deduced whether effluent infiltration takes place mainly through the wetted bottom of the trench, or mainly through the sidewalls, or equally through both. Tensiometers also provide information on the degree of soil saturation, with a matric potential of approximately zero indicating a saturated soil. From all this information the long-term effluent absorption rate during relatively wet periods (LTAR) for the system and the site can be calculated.

The next step was to determine if a rough empirical correlation existed between LTAR values measured at all the experimental sites, and the local soil hydraulic conductivities measured using the Talsma and Hallam method. If such a correlation exists, it can be used to predict the appropriate size of a new system in any soil of which the hydraulic conductivity has been measured.

3.4 System performance, also during periods of waterlogging

Figure 2 illustrates the movements of the ponding level in both trenches at North Whittlesea in response to rainfall. Between July and October 1978 the disposal system was only just coping under the then prevalent extremely wet conditions. The upper trench occasionally suffered from a positive total potential, apparently because natural seepage was entering the trench on the upslope side. This occurred in the period between 7 and 18 August as a result of about 110 mm of rain in four successive days, followed by still more rain. The August total of 175 mm rain is 50% greater than the mean. The lower trench was not under such stress. During the latter half of September 1978 similar conditions prevailed.

Iso-potential lines (Fig.3) indicate that the clogging layer on the trench bottom was limiting but not totally inhibiting vertical infiltration, and that the main direction of infiltration was laterally through the more permeable sidewalls (A and AB horizons). LTAR for the system was at least 8 L/m^2.day or 8 mm/day through these sidewalls, even during the very wet periods. Evapo-transpiration was insignificant over the long cold winter period.

The new trenches constructed in October 1978 after one year had a very similar LTAR of just over 7 L/m^2/day or more. These trenches also coped well during a very wet September (146 mm of rainfall, 47% higher than average for that month) and early October (131 mm during the first two weeks) in 1979.

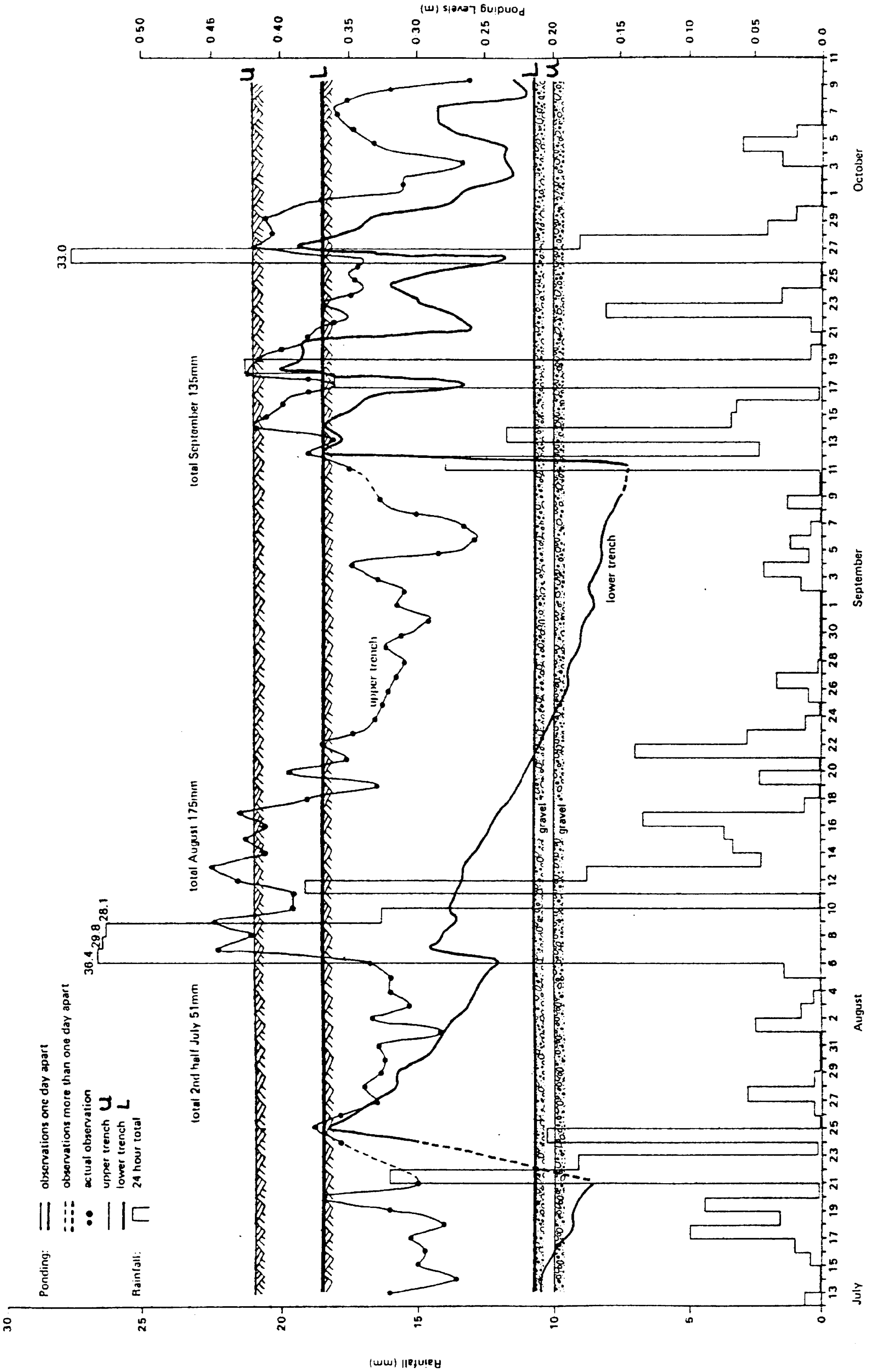


Figure 2 24 Hour rainfall and levels of ponding of effluent in the trenches (old system) at North Whittlesea, from July to October 1978. Note the response of ponding level to rainfall events and the lower ponding levels in the lower trench. The position of the top of the gravel backfill and the topsoil cover are indicated in the diagram.

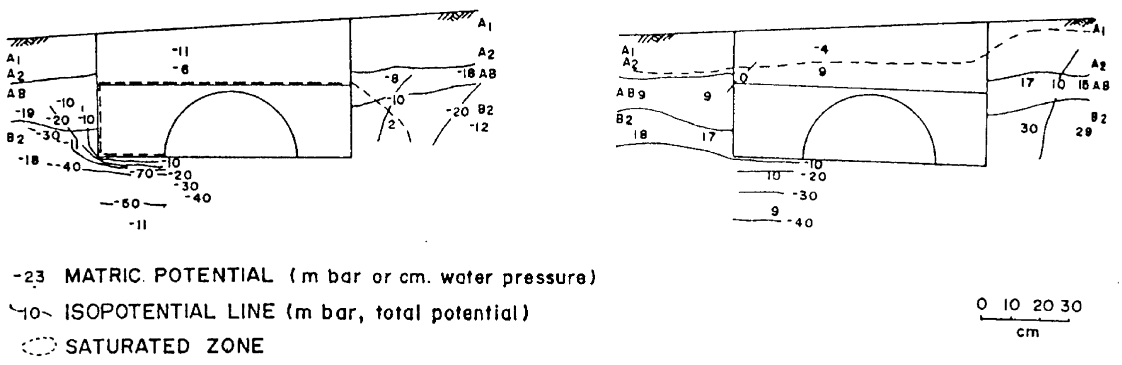


Figure 3 Iso-potential lines and local perched water tables at North Whittlesea during a dry period in mid-winter (left, 3 August 1978) and a subsequent very wet period (right, 7 August 1978). Note the rapid response of the water table in the trench and the surrounding soil to high rainfalls. The spacing of iso-potential lines below the trench also shows increased vertical drainage during the wet period compared to the dry period, which is a compensating factor.

It is noteworthy that sampling of soil water within a few metres of the trench gave no indication of pollution during any of these wet periods. The fact that a water table in the trench exists at ground surface in the trench does not prove that it is the effluent, which has risen to the surface. If the loading of the trench does not exceed its LTAR (in this case 8 L/m^2.day), the water at the surface will be rainwater. Figure 3 shows how, even under wet conditions, effluent movement from the trench is mostly downward into the unsaturated soil below. Simultaneously, of course, there is also flow from the upper trench into the lower.

In 1979, with the new trench system operating, tensiometers were also installed in a control location without effluent absorption trenches. The position of the intermittent water table in the control site and at the trench is shown in Figure 4. Note that during the dry period (on 20 July 1979, again in mid winter!) the saturated zone in the trench reached to the top of the Reln drain and extended a short distance into the soil on the upslope side of the trench, but not elsewhere in the surrounding soil. In the control, there was no evidence of saturation at all within about 0.6 m depth. During an intermediate wetness period in early spring (4 October 1979), saturation rose into the topsoil cover within the trench, and was detected at about 0.4 m in the control. During a wet period three days later the local perched water table came to the ground surface in the trench and remained some 50 mm below the surface in the control. However, the trench still had not failed.

These results prove indisputably that intermittent soil waterlogging does not inevitably lead to absorption failure, and that the maximum level to which a perched water table may rise in a soil profile has no bearing on soil suitability for on-site disposal. Of greater importance is the duration of waterlogging. A second important outcome is that permanent or true water tables must not be equated with intermittent seasonal shallow water tables. Thirdly, interceptor drains can easily solve the problem of perched water. Fourth, if LTAR values for specific soil and climatic environments have been obtained empirically over a long period, including wet and or cold seasons, these already incorporate drainage rates during these critical times.

4 A Disposal Field Sizing Curve and Sizing Equations, based on Field Data

4.1 Disposal field sizing curve

Of the thirteen operating septic tank effluent systems studied by Brouwer (1982) only one, at Wollert, experienced major problems. The problems there were caused by a shallow permanent groundwater table, which moved up and down between 0.2-0.5 m depth. Eight other systems, at Doncaster-Templestowe, Eltham, Kangaroo Ground, Lara and Bacchus Marsh, were subject to various degrees of intermittent seasonal waterlogging, i.e. perched water tables on a low permeability subsoil, particularly in winter. All eight performed even better than the system at North Whittlesea. The three other systems were on permeable red earth soils. The LTAR's of all twelve properly functioning systems were plotted against the local soil permeability values or saturated hydraulic conductivities. Underneath these points a sizing curve was drawn, which formed the basis of the disposal field sizing curve in the 1990 Victorian Septic Tank Code of Practice[2] (EPA 1990) (Fig. 5).

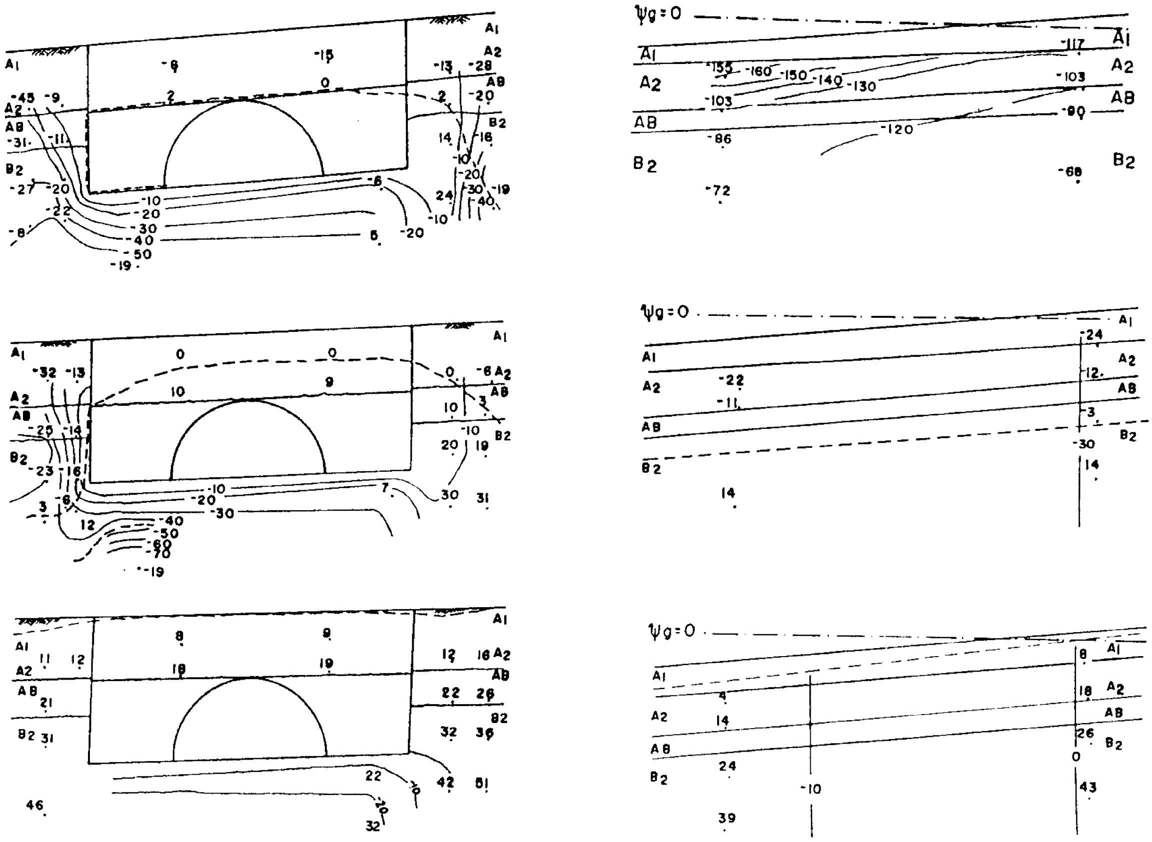


Figure 4 Iso-potential lines and local perched water tables around an absorption trench and a control site at North Whittlesea during 20 July 1979, a dry period (top row), 4 October 1979, an intermediate period (middle row) and 7 October 1979, a wet period (bottom row).

4.2 Optimising absorption trench length using trench storage capacity and evapo-transpiration for a period in the year with 'wet' months

Those interested may have noticed that the sizing curve in Appendix 4 of the 1990 Victorian Septic Tank Code of Practice takes account only of local soil permeability. It takes little or no account of main infiltrative surfaces (bottom, sidewall or both, depending on the soil type); of local rainfall, pan evaporation and runoff; of vegetation effects on effluent disposal rates; or of storage capacity of the

[2] Unless the loading of a disposal trench system as well as the size of its wetted sidewall and bottom area throughout the year are quantified, all attempts to find an LTAR are merely guesses. To this day, Brouwer's work has not been repeated for other areas in Australia, although the Australian Standard 1547 and various State Codes all rely on LTAR values for determining the size of a new disposal area.

trench for tiding over wet periods. Brouwer (1982) and Brouwer and Bugeja (1983) incorporated these factors in a simple series of equations to calculate the optimum length of absorption trench. In these equations it is assumed that the infiltration rate into the soil remains constant during the year, but that the evapo-transpiration component varies with the seasons.

As a starting point, effluent inflow into a disposal field must equal, but not exceed, the combined output by infiltration and evapo-transpiration. Thus for any given month:

$$V_i = L_i\,(I.T_w.D_i + E_{ei}.W_e) \qquad \text{(Eq. 1)}$$

Where V_i = monthly inflow in L/month (for an average month of 30.5 days, based on 1000 L/day in this example, V_i = 30,500 L/month)
L_i = length of trench required (m)
I = infiltration rate, for which an experimentally-based or other safe LTAR value may be used (L/m^2.day)
T_w = wetted trench area, based on trench width and/or maximum ponding of 0.25 m depth (m^2)
D_i = average number of days per month (30.5)
E_{ei} = average actual effluent evaporation during month i (mm)
W_e = effective width of trench for evapo-transpiration, including adjacent border zones (m)

The average actual effluent evaporation, E_{ei}, is calculated using a crop factor of 0.75 as a multiplier for pan evaporation, E_o, to estimate effluent evapotranspiration from a grassed surface. For a surface with non-deciduous trees and shrubs the crop factor was taken to equal 1.0. Brouwer's work in the outer Melbourne area indicated that the adjacent border zones participating in evapo-transpiration are 0.3 m wide on either side in a grassed area (W_e = width of trench plus 0.6 m), and 1.0 m wide where there are non-deciduous trees and shrubs. However, during so-called 'wet months', when the monthly effective precipitation, P_e, is greater than actual evaporation, the width of the participating border zones is take to be zero. P_e equals the actual rainfall minus the proportion that runs off. Burton's table (Burton, 1965) provides empirical rule of thumb values for the proportion of runoff as a function of slope gradient, vegetation cover, surface micro-topography, and rainfall intensity.

Next, the sum of excess volumes of effluent for each of i successive 'wet' months must be smaller than the storage volume, S_t (in L) in the trenches to estimate the optimum design trench length, L_d (in m):

$$\Sigma\ \{(L_{iw} - L_d) / L_{iw}\}\ V_i \leq S_t.L_d \qquad \text{(Eq. 2)}$$

where L_{iw} is the length of trench required (m) during each i 'wet' month. It is assumed that at the end of a dry period the remnant volume of effluent in the trenches is small and may be ignored. For a number i of 'wet' months, L_{iw}, Equation 2 can be rewritten as :

$$\{i - L_d.\Sigma(1/L_{iw})\}\ i.30{,}500 \leq S_t.L_d \qquad \text{(Eq. 3)}$$

or

$$L_d \geq (i.30{,}500) / \{S_t + 30{,}500.\Sigma\ (1/L_{iw})\} \qquad \text{(Eq. 4)}$$

To use this optimisation, it is necessary to determine that the accumulated stored effluent can indeed be disposed during the following dry months. As an example of such an optimisation for effluent disposal trenches in Ringwood, Victoria, using a 0.5 m wide trench with fibre glass reinforced corrugated arching (RELN drain) is given below. The stable effluent infiltration rate is assumed to be (only!) 4 L/m^2/day. The storage capacity of the RELN drain equals the total volume under the arch plus the voids volume in the screenings backfill. The space under the arch is about 80 L/m length and voids in the screenings occupy, say, 40% of their volume, making a total pore space of about 97 L/m for 1 m of trench of 0.5 m wide and

0.25 m deep.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eo			146	94	60	38	47	62	89	130		
Et*)			110	70	45	29	35	47	67	97		
P			60	78	84	68	72	81	80	92		
Pe**)			42	55	59	48	50	57	56	64		
(Et-Pe).We			74.8	16.5	-7.0	-9.5	-7.5	-5.0	12.1	36.3		
Type of month			dry	dry	wet	wet	wet	wet	dry	dry		
Li			155	220	265	271	266	261	227	193		

*) Crop factor = 0.75. **) Runoff proportion = 30%.

So that:

$$Ld \geq (4 \times 30{,}500) / \{97 + 30{,}500 \times (1/265 + 1/271 + 1/266 + 1/261)\} = 219 \text{ m}$$

5 Discussion and Conclusions

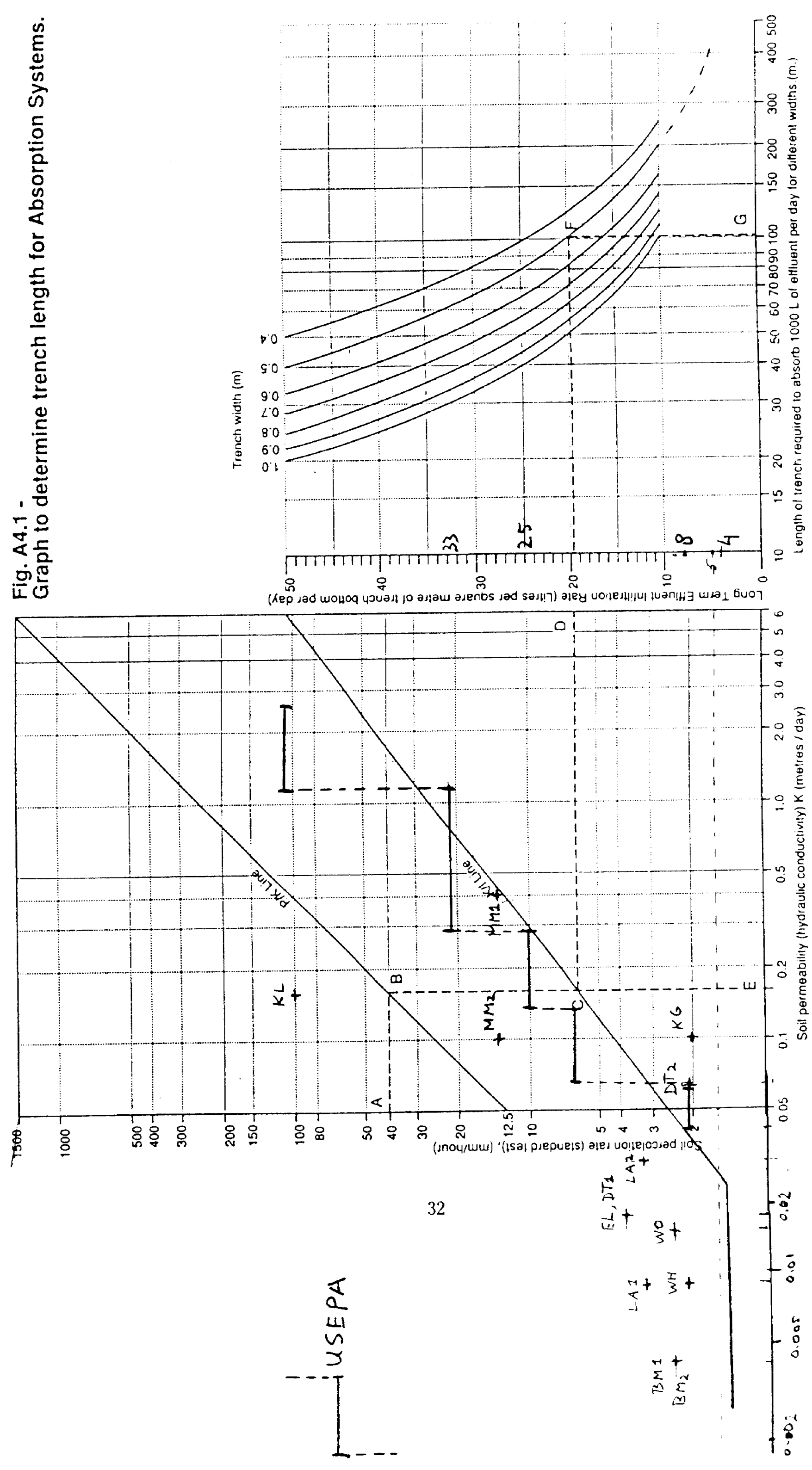
As we have demonstrated, waterlogging does matter to on-site effluent disposal, but to assess its impact one has to consider it from a sound hydrological perspective. The idea that any seasonal, intermittent shallow (perched) water table in a soil, regardless of duration, renders it unsuitable for effluent disposal, is incorrect. The idea that the minimum depth of a perched water table below the ground surface is a reliable criterion for judging soil suitability is equally incorrect. In this respect, most land capability rating tables are based on faulty intuition and have not been confirmed and calibrated by field experiment.

The position and movements of a true water table are of far more importance to soil suitability for on-site disposal of effluent. Therefore perched water tables, which nearly always are intermittent, must be evaluated in a different way from permanent water tables. Such evaluation should initially be on the basis of long-term soil water and disposal field monitoring, but in the longer run it may be possible to make sound inferences regarding duration of waterlogging on the basis of soil profile colours and mottles (cf. Brouwer and Fitzpatrick, in press). Artificial drainage will generally alleviate or overcome intermittent waterlogging.

We have also shown how duration of waterlogging, vegetation type and other site characteristics relevant to the water balance, can be taken into account when sizing an effluent disposal field. This sizing method, too, has been based on detailed observation of effluent disposal systems in the field, and comparison with local soil permeability or saturated hydraulic conductivity rate. There really is no adequate substitute for such observations if sizing of disposal systems is taken seriously. See also van de Graaff and Brouwer, 1998a and 1998b.

From the fact that effluent absorption continues during periods of waterlogging, it follows that the notion that soil permeability needs to be measured when the soil is saturated is hydrological nonsense. Permeability tests should be done when the permeability, an intrinsic property of the soil, can be accurately determined. i.e. when water can drain as freely as it ever can at a particular site. That is how the relationship between LTAR and soil permeability should also be determined. Any hindrance to effluent absorption from waterlogging is then already incorporated into the LTAR.

Incorrect premises and concepts, in effluent disposal or elsewhere, can never be defended on practical or on "best environmental management" grounds. Soil science professionals ought to be more active in helping environmental managers to understand the soil hydrological system.



Figur e 5

Figure A4.1 is an empirical sizing diagram used in the 1990 Code of Septic Tank Practice and based on Brouwer's (1982) LTAR data for twelve Victorian sites. The diagram was constructed to enable either hydraulic conductivity data or percolation rates resulting from the Code's prescribed test method to be used to determine LTAR values. The P/K line relates percolation rate to hydraulic conductivity. The USEPA (Otis et al., 1980) sizing diagram has been added for comparison.

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