

User Manual for the Daily Disposal Computer Model

INTRODUCTION

Equation Section 1

As an adjunct to Clarence Valley Council's On-Site Sewage and Wastewater Management Strategy (CVC 2005), a computer model was created by Antony McCardell (based on Lismore City Council's existing waste water model) to assist in the sizing of land application areas, particularly evapotranspiration-absorption (ETA) trench-type systems and irrigation-type systems (SDI).

The computer model simulates some of the processes involved in on-site disposal of wastewater. It is based on published technical material in the literature of wastewater management and associated fields and is similar in many respects to other models. This model includes user interface features such as list boxes, check boxes and buttons from which parameter values may be chosen. These are also replicated in tables in this text. *It is recommend that Step by Step Examples be followed and tried by consultants, in order to become familiar with the operation of the model.*

Land application areas

In this document land application area (LAA) refers to the physical entity being the area of land onto which treated domestic effluent is to be applied, but more commonly to the numerical size in metres squared (m²) of that land, the precise intended meaning in any one instance being dictated by the context. The model's primary purpose is to calculate the LAA size based on

- 1) Total Nitrogen (TN) loading, with N loss via plant uptake and seepage below the root and gravel zones.
- 2) Total Phosphorus (TP) loading, with P loss via plant uptake and soil adsorption.
- 3) Hydraulic loading, with water loss via plant evapotranspiration and percolation.

The LAA size must be able to accommodate all three processes in order to protect surface and ground water, human health and ecosystems.

User Input Parameters

Once opened, the Microsoft Excel spreadsheet containing the model is ready to receive various parameters. Cells with text highlighted in blue are reserved for data entry of site-specific parameters which cannot be chosen from pre-set values, an example of which would be the allotment size. Cells which are not for data entry, or are defaults resulting from choices made within list boxes, are left unhighlighted in black. Values provided in list boxes, check boxes and buttons provide suggestions based on the literature. A user may wish to input alternatives but would need to substantiate them by reference to on-site tests, recent literature etc.

Default parameters and user-defined parameters

The **Clear** button resets the model's default parameters. An actual application requires resetting at least some of these. To overwrite a default parameter, enter a value in the user-defined column.

SITE PARAMETERS

Block Size

The allotment size is required later in the calculation process to ascertain permissible N loadings on the allotment. It is entered as meters squared (m²), hence 1 ha would be 1 0,000m².

Buffer from land application area to stream/gully

This list box offers a choice between two kinds of buffer which apply when the LAA is within either the permanent water buffer of 100 m or the intermittent water buffer of 40 m (DLG *et al.* 1998). Due to the high rainfall of the region, Council now classes any stream (permanent or intermittent) as requiring a 100 m buffer. Similarly all gullies (which have the potential to become intermittent waterways in wet weather) are now considered to require a 40 m buffer. The actual distance from the point on the LAA nearest to the gully or stream is entered into the appropriate user-defined cell only if the LAA is unavoidably situated within the buffer. If the LAA is outside any buffer, then no user-defined input is required.

Water supply type

The water supply type and water efficiency of the household fixtures greatly influences the rate of wastewater generation, shown in Table 1 (the source of the default values in the model). In this table, standard water-reduction fixtures include dual flush 11/5.5 litre water closets, shower-flow restrictors, aerator faucets (taps) and water-conserving automatic washing machines. Full water-reducing fixtures include the combined use of reduced flush 6/3 litre water closets, shower-flow restrictors, aerator faucets, front-load washing machines and flow/pressure control valves on all water-use outlets. Additionally, water reduction may be achieved by treatment and recycling of greywater for the purpose of toilet flushing.

Table 1 : Typical domestic wastewater flow generation, litres per person per day (AS/NZS1547:2000)

Source	On-site roof water harvesting water supply (L/p.d)	Reticulated, community supply from borehole, creek or spring (L/p.d)
Household with standard facilities (including automatic clothes washing machine)	140	180
Household with standard water reduction fixtures	115	145
Household with full water reduction facilities	80	110
Households with extra wastewater producing facilities	170	220

Bedrooms

This is the design ‘number’ of persons contributing to the wastewater stream, calculated as the number of bedrooms multiplied by 1.5.

Within the workings of the model (but transparent to the user) the ‘number of persons’ is adjusted downwards according to the proportions of wastewater generated by the facilities contributing to the wastewater stream. No adjustment is made when all the wastewater components are present. The total wastewater flow (L/d) is automatically calculated as:

$$\text{Total_flow} = (\text{No_persons} \times 1.5) \times \text{Daily_flow_per_person} \quad (1)$$

WASTEWATER COMPONENTS

Opinion differs on the typical proportions of hydraulic flow, Total Nitrogen (TN) and Total Phosphorus (TP) within the blackwater stream relative to the total wastewater stream (Table 2).

Table 2: Proportion of greywater component to total standard wastewater for Flow, TN, TP

	Flow	TN	TP
Greywater alone: proportion to total conventional wastewater stream	68% (Jeppesen & Solley, 1994)	30% midrange of 20%-40% (DLG <i>et al.</i> , 1998)	60% midrange of 50%-70% (DLG <i>et al.</i> , 1998)
	65% (DLG <i>et al.</i> , 1998)	32% (Witt <i>et al.</i> , 1974)	87% (Witt <i>et al.</i> , 1974)
		18% (Siegrist, 1977)	70% (Siegrist, 1977)
Blackwater alone (Toilet)	32%	70%	40%

The blackwater figures in bold are adopted as defaults within the model for the proportion of blackwater to total wastewater for water flow, TN and TP.

Where only a proportion of a conventional wastewater stream is to be disposed of, **check boxes** may be ticked to indicate which facilities contribute to the wastewater stream. ‘Bathroom’ comprises shower, bath and basin while ‘Kitchen’ includes sink and dishwasher.

Where composting toilets are installed the blackwater stream is either bypassed entirely, so the toilet check box would not be ticked.

Table 3 was used to supply proportional flow rates for the hydraulic component of the check boxes (Jeppesen & Solley 1994). These figures are for Brisbane but due to similar climate may be applied to our region. Jeppesen & Solley used data from studies in Perth (in 1985) and Sydney (in 1993) to arrive at their estimates.

Table 3 : Average in-house water usage, indicating proportion of wastewater attributable to constituent sources.

Shower	Bath	Basin	Kitchen	Laundry	Toilet	Total greywater	Total	Source
28%	5%	5%	7%	23%	32%	68%	100%	Jeppesen & Solley (1994)
Bathroom								
38%			7%	23%	32%		100%	Adopted in CVC model

SOIL INFORMATION

This is the only section of the model that is affected by the ‘Simplified – Advanced’ user info options. Various soil related information is required in this part of the model, this information is required for both the hydraulic and phosphorus sub-models.

Advanced

Morand soil landscape code

The first list box in this section of the model requires the user to consult Morand (1994) *Soil Landscapes of the WOODBURN 1:100 000 Sheet*. The list box contains all of the Morand soil

landscapes found in the North Eastern CVC jurisdiction. These are indicated by 2-letter codes and are grouped into a few broad categories.

The Morand soil landscape categories are required by the model to calculate the phosphorus area. Each category has an indicative phosphorus sorption value which is supplied as a default. Because the results of soil tests at local laboratories often contain phosphorus sorption data, this default may be over-written with a user-defined value when more precise data is available.

If the Morand soil landscape categories do not cover your specific area then please refer to the simplified option of this instruction manual.

Simplified

The first list box in this section of the model requires the user to select a simple soil category (sand, loam or clay). The list box contains three common soil landscapes found in the CVC jurisdiction. These soil categories are given conservative phosphorus sorption values which are supplied as a default.

Because the results of soil tests at local laboratories often contain phosphorus sorption data, this default may be over-written with a user-defined value when more precise data is available.

Depth to water table or bedrock

The depth to the water table or bedrock is required to calculate the phosphorus area. This is a difficult parameter to estimate (short of drilling or digging). The situations in which it is likely to have an important bearing on the phosphorus area are those where the water table is shallow or the bedrock relatively close to the surface. Every effort should be made to discover this depth in these circumstances. If the depth is known to be greater than about 3 m then the actual value entered is unlikely to affect the calculated phosphorus area.

Texture/Structure

The soil's texture and structure is a very important parameter in the model as it determines the percolation rate of treated effluent, and therefore has a great bearing on the calculated hydraulic area.

The texture/structure categories refer to the soil underneath the ETA bed or SSI system. The categories are taken from AS/NZS 1547:2000 as described in the parent document. Whilst the structure/texture should be determined from bolus tests and inspection, Morand (1994) provides good indications of the kinds of texture/structure likely to be encountered within any one soil landscape. Council does not endorse the routine choice of "clay loam – high/moderate structured" that have consistently appeared in some consultants' reports.

The texture/structure of a soil is the main determinant of the maximum deep drainage rate (percolation rate), displayed upon choosing the texture/structure.

TREATMENT SYSTEM

The treatment system parameters reflect the ability to remove total nitrogen (TN). The model requires several N parameters, principally the nitrogen removal percentage, the default value for this being set by choosing a **Treatment system** from the list box.

Nitrogen removal %

Choose the treatment system from the list box provided. Each system has a default TN removal percentage displayed upon choosing a system. Septic tanks (DLG *et al.* 1998) and single pass sand filters (Patterson 1994) do not significantly reduce N levels. “Secondary generic” refers to any system not otherwise specifically listed. Thus a single pass sand filter would be classed as “Secondary generic”. Being aerobic, it would be unlikely to remove significant TN (lacking the anaerobic conditions to denitrify). In this case the default 0% would be left unmodified. If the sand filter were a recirculating one, then the default could be over-written with an appropriate value, reflecting the ability of recirculating sand filters to denitrify effluent. AWTSSs reduce TN probably no more than 20% (Hagare, P., *pers. comm.* 2001), with some recent systems claiming to achieve higher. Data soon to be published by NSW Health may cause this figure to be revised. Reed beds typically remove 50% TN where the design allows for 7 day’s residence time (Davison *et al.*, 2000).

Reed beds

If a reed bed is chosen as the secondary treatment device then another default parameter is presented: the wetted depth of the reed bed (m). This is traditionally 0.5 m but can be otherwise.

There are two kinds of reed bed scenarios. The first, “Reed bed – BOD 20 mg/L” refers to a reed bed that is sized to meet the accepted secondary treatment standard of 20 mg/L of BOD. The assumption is that a full wastewater stream from a septic tank has a BOD concentration of 250 mg/L when the wastewater generation rate is 115 L/p.d, higher generation rates resulting in a proportionally more dilute BOD concentration. The default TN removal percentage under the “Reed bed – BOD 20 mg/L” scenario is calculated to be the value which would coincidentally provide the “BOD 20 mg/L” level of secondary treatment. This default value displayed would vary depending on other choices made in the spreadsheet. The other, “Reed bed – variable TN % removal specified” refers to a reed bed in which the default TN removal percentage is a flat 50%, which may or may not provide the strict secondary treatment level of BOD 20 mg/L. Approval of such a treatment system would be at the discretion of Council.

Allowable Total Nitrogen export load

A final parameter “Maximum N allowed to go down from the system” is the default TN export allowance for any one LAA. Overwriting the default value of 15 kg/system.yr would only be allowed in exceptional circumstances.

LAND APPLICATION

The land application list box offers a choice between ETA beds, Septic Absorption trenches and Subsurface drip irrigation (SDI) systems only.

Depth of layers in ETA beds

If ETA beds are chosen, then two further parameters are required: 1) the depth of the soil layer above a gravel layer, also called the root zone because it contains the roots of a planted vegetative cover, which is assumed to be mown grass, and 2) the depth of the gravel layer beneath it. The bottom of the gravel layer comprises the bottom boundary of the conceptual “leaky bucket” that is used to calculate the hydraulic area. The default value of 150 mm for each of these parameters is likely to vary according to the ETA design, and user-defined values will likely be required. Various designs for ETA beds are available in the parent document.

Depth of layers in Absorption Trenches

Absorption trenches are given as a disposal option for Primary treatment on large lots with appropriate soil types. If Absorption trenches are chosen, then one parameter is required: 1) the depth of the trench. The default value of 600mm for this parameter is unlikely to vary according to the Absorption trench design.

Depth of the root zone in SSI system

If a SSI system is chosen, then only one other parameter is required, being the depth of the root zone which is the depth of the conceptual “leaky bucket” in this kind of land application system.

Area calculations

The model returns the hydraulic, nitrogen and phosphorus areas. The largest of the three areas is the limiting design factor and becomes final design LAA. In addition, if a reed bed is chosen as a secondary treatment device, the area of the reed bed and the reed bed’s hydraulic retention time is also reported.

MODEL WORKINGS

Hydraulic sub-model

The climate in the Northern Rivers area stands apart from the rest of NSW with its heavy summer rainfall and higher average temperatures. This justifies a local water balance approach, as indicated in AS/NZS1547:2000. The hydraulic area calculation is based on a daily water balance performed within a domain, the boundaries of which are the surface of the trenches or beds, their sidewalls and basal areas. This domain may be conceived as a “leaky bucket” being permeable at the basal area (Figure 1). Our hydraulic sub-model conforms in many ways to a traditional Leaky Bucket mathematical model which is essentially a flow equalisation model with variable net inputs but a constant output. In the hydraulic sub-model this output is identified as the percolation component. However the output in our model is not exactly constant, but has a constant upper limit which is often realised in wet weather. In short the “leaky bucket” is used only as a convenient metaphor. This spatial domain is henceforth unceremoniously referred to as the “bucket” for short.

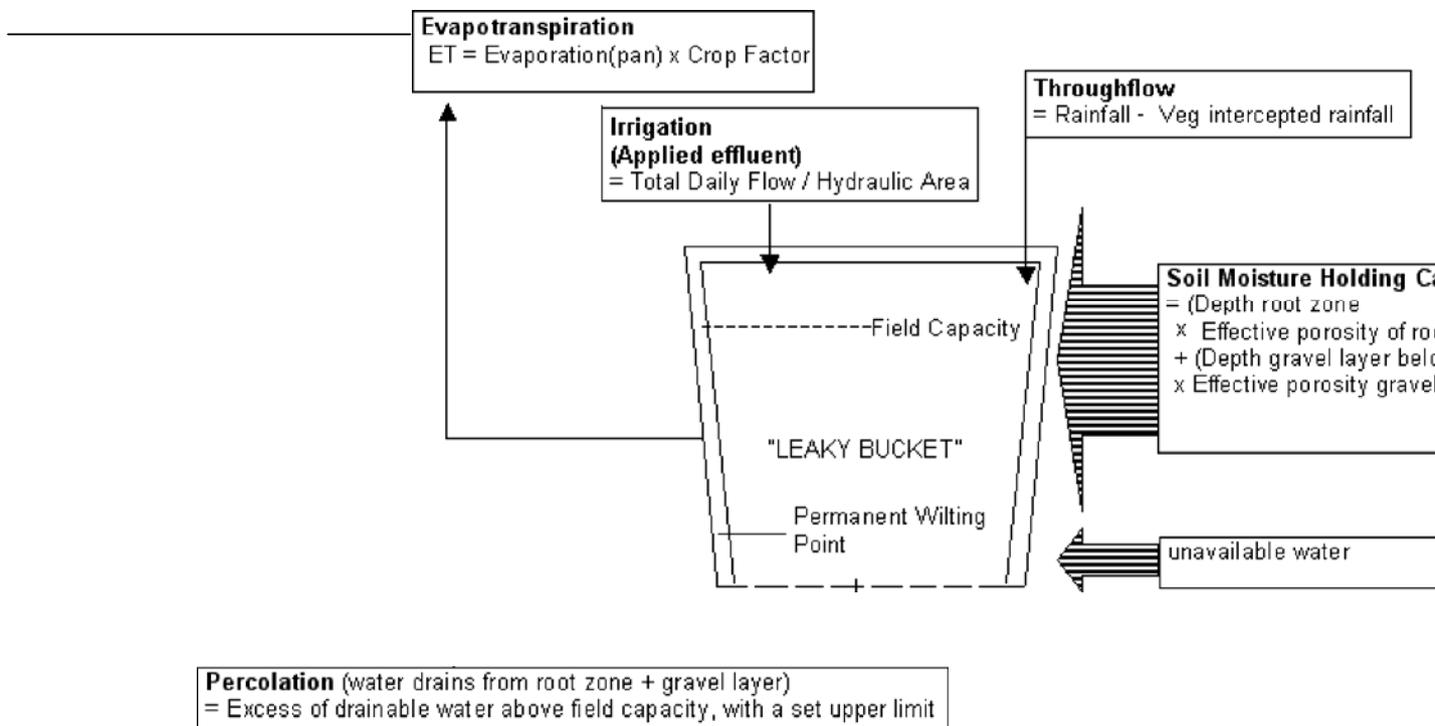


Figure 1 : Conceptual “Leaky Bucket” representation of the Daily Disposal Model.

A daily water balance is kept for all inputs and outflows, although the balance itself is limited by the approximations used and the assumptions of homogeneity of the land and evenness of distribution of effluent. The balance is based on daily rainfall and evaporation records. In simple terms it may be expressed as

$$\text{Bucket} = \text{Bucket}_{t-1} + \text{Throughflow} - \text{ET} - \text{Perc} + \text{Irrigation} \quad (2)$$

where Bucket is soil moisture storage in the bucket at the end of the current daily period

Bucket_{t-1} is soil moisture storage in the bucket at the end of the previous daily period

Throughflow is depth of rainfall reaching the soil and infiltrating during the current daily period

ET is evapotranspiration during the current daily period

Perc is drainage of water from the bucket into soil below during the current daily period

Irrigation is depth of effluent applied to the LAA during the current daily period

Note that this model does not take runoff into account, as this does not occur on 95% of the days within the modelling period, as elucidated below. Further, additional refinements are not shown in Eq. (2), but are described in the following sections.

The hydraulic model was originally a translation of a FORTRAN program (Fiander 1980). Fiander's program is based on an unpublished "bucket" model by W. Boughton (undated but c.1980), then of the Water Resources Commission (Fiander, *pers. comm.*, 2003). However the original model has been modified extensively in the current version. The daily water balance is calculated on 21 years (1 July 1970 - 30 June 1991) of rainfall and Class A Pan Evaporation data from local weather Stations. Hence the model is applicable only to areas within this general climatic area.

Hydraulic Area (m²)

A hydraulic area is calculated iteratively so that it is made sufficiently large to allow percolation out of the basal area of the ETA bed or SSI root zone on 95% of the days in the rainfall history. The following sections detail the calculations used in the water balance.

Rainfall and Throughflow

Not all the rain that falls on the LAA is capable of infiltrating. A small amount will be intercepted by the vegetative cover. The model assumes that the maximum intercepted is 4 mm. The calculation of rainfall that is capable of infiltrating (throughflow) is based on an algorithm from a European model (Kroes & van Dam 2003) where throughflow is based on physical properties of vegetation such as leaf area index (LAI) and percentage cover. The assumption for our model is that the LAI is 3 and the percentage cover 100%. An empirical coefficient 'a' determines the limit of rainfall interception. (LAI * a) is the asymptote of rainfall capable of being held above ground by the vegetation as interception. For most regular agricultural crops the value of 'a' is about 0.25 (Kroes & van Dam 2003), thus for those crops with a LAI of 3 the asymptote of interception would be 3 x 0.25 = 7.5 mm. As mown grass would be expected to hold less intercepted water than most agricultural crops, a lower value of a = 0.133 is used to give an asymptote of 4 mm (i.e. the maximum rainfall interception). For example, with these parameters, the rainfall interception is 2 mm when the daily rainfall is 4 mm and the interception is 3.7 mm when the rainfall is 50 mm. Under our assumptions the original formula (Kroes & van Dam 2003) simplifies to Eq. (3)

$$\text{Throughflow} = \text{Precipitation} - 4 \times (1 - (1 / (1 + \text{Precipitation} / 4))) \quad (3)$$

where Throughflow is the depth of water (mm) that arrives on the soil from precipitation, after some is intercepted by vegetation (here grass) and the value 4 is the (LAI * a), the asymptote of intercepted rainfall.

The reader is referred to the original formula (Kroes & van Dam 2003) for further details.

Note that this refinement has only a minor effect on the calculation of LAA, which is heavily influenced by the water balance under conditions of very high rainfall.

Evapotranspiration and the Pan Evaporation Crop Factor

"Crop factors" convert the Weather Station Class A Pan Evaporation data to evapotranspiration of the vegetation growing on the LAA, which is taken to be equivalent to a grass cover resembling the Penman-Monteith reference crop evapotranspiration. Crops other than mown grass are discouraged unless appropriately supported by crop coefficient data. The aim is to encourage evapotranspiration. The choice of vegetative cover must be balanced against the need to prevent damage to piping etc from root intrusion, hence the recommendation that mown grass be used. Eq. (4) is based on the reasonable assumption that in a LAA the grass will never be short of water, hence actual ET will always be equal to potential ET. This greatly simplifies the model.

$$\mathbf{ET = Pan_evaporation \times Crop_factor} \tag{4}$$

where Pan _evaporation is the monthly Class A pan evaporation (mm) and Crop_factor is a coefficient. Daily crop factors are the same within any one month, and the monthly crop factors are based on seasonal crop factors for Brisbane established through regression analysis of pan evaporation data against Penman-Monteith reference crop ET data (Grayson *et al.* 1996).

Percolation rates (mm/day)

Eq. (5) is the formula used to calculate the percolation component of the water balance.

$$\mathbf{Perc = \min(Max_perc, \max(0, Bucket_{t-1} - Bucket_{awc}))} \tag{5}$$

where Perc is the depth of water (mm) that is lost to percolation (deep drainage)

Max_perc is the design percolation rate

Bucket_{t-1} is the depth of water in the bucket on the previous day

Bucket_{awc} is the depth of water in the bucket after it has been allowed to drain to the field capacity of the soil layer within it (generic soil data from Dunne & Leopold 1978).

This formula is saying that percolation cannot be greater than the design percolation rate and cannot be smaller than the remainder left in the system from the previous day less the amount that is not able to drain away under gravity. The term in Eq. (5) that has by far the greatest influence on the water balance is the design percolation term Max_perc which equals Perc on very wet days.

Percolation rates for ETA beds (mm/day)

The design percolation rates used in the hydraulic sub-model for ETA beds are taken to be equal to the long term acceptance rates (LTAR) for the particular soil textures and structures. In turn design loading rates (DLR) for “trenches and beds” in AS/NZS1547:2000 (p.116) are used as surrogates for the LTAR values. AS/NZS1547:2000 (p.114) reports that these DLR values were estimated using LTAR in conjunction with “the quality of effluent and the likelihood of clogging layer development”, but the exact relationship is not reported and representative LTAR values are not given. However the document does stipulate that “The assigned DLR values are lower than the estimated LTAR for the soil.” (AS/NZS1547:2000, p113), and “When designing a land-application system the DLR must never exceed the estimated LTAR” (AS/NZS 1547:2000, p.114). Hence the use of DLR to represent LTAR and, in turn, the percolation rate, is conservative.

Percolation rates for pressurised subsurface irrigation

The design percolation rates used for subsurface irrigation (SDI) are between 10 mm/d for the most permeable soil type (gravels and sands) and 3.5 mm/d for dispersive soils. The design irrigation rates (DIR) for irrigation systems in AS/NZS1547:2000 (p.125) were trialed as design percolation rates

but this gave a percolation rate that was too conservative, resulting in hydraulic areas that were too large. Due to the radical uncertainty of what values to use, and the variation in recommended DIR from various SDI pressurised pipe manufacturers, the revised model allows SDI industry practitioners to enter their own values for the hydraulic area, based on their own industry practices, subject to Council approval.

Capacity of the bucket

When the actual percolation rate is less than the maximum rate in Eq. (5) it is controlled by the amount able to drain out of the bucket over the course of a day. The capacity of the bucket is controlled by the depth and porosity of the porous media within it. In all the hydraulic calculations areal depth of water (mm) refers to the depth adjusted for the porosity of soil or gravel within the bucket.

Depth of root zone

The first (obligatory) layer is the root zone where evapotranspiration occurs in both ETA beds and SSI systems. In an ETA bed this is the layer of soil containing roots above the gravel layer (Figure 2). In a SSI system this layer is assumed to occupy the whole of the bucket.

Depth of gravel layer below root zone (m)

The second layer underneath the first, which is present only in ETA beds, is typically a layer of gravel (mostly bluemetal in the CVC area) (Figure 2).

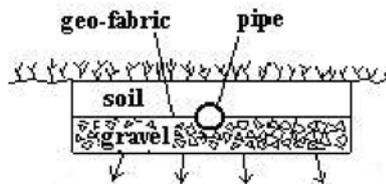


Figure 2. The two layers of an ETA bed

Effective porosity and available water of root zone and gravel layer below root zone

The water holding capacity of the root zone of the bucket, the *effective porosity*, is constrained by the permanent wilting point (PWP) at which the water cannot be extracted from soil particles by the action of plant roots.

$$\text{Eff_porosity} = \text{porosity} - \text{PWP} \tag{6}$$

Available water is technically the volume ratio of voids that remain filled with water after drainage from saturation over two days (though most of it drains within a single day) and which remains available for plant root uptake. In our model drainage to the level of available water is assumed to be accomplished in a single day.

$$\text{Available_water} = \text{Field_capacity} - \text{PWP} \tag{7}$$

Bucket (as in Buckett-1) in Eq. (5) is the soil moisture content of the bucket. The maximum possible soil moisture content on any one day (at saturation) is

$$\text{Bucket}_{\text{sat}} = (\text{Depth}_{\text{rootzone}} \times \text{Eff_porosity}_{\text{rootzone}}) + (\text{Depth}_{\text{gravel}} \times \text{Eff_porosity}_{\text{gravel}}) \tag{8}$$

In Eq. (8) the moisture content below permanent wilting point is not considered to be part of the bucket's content as it represents water permanently attached to the soil particles.

Bucket_{awc} in Eq. (5) is the soil moisture holding capacity of the bucket at field capacity. It is defined in Eq. (9), where the available water capacity (AWC) of gravel is assumed to be zero (Table 4). Hence the term in the right-most bracket in Eq. (9) can be ignored under normal circumstances.

$$\text{Bucket}_{awc} = (\text{Depth}_{rootzone} \times \text{AWC}_{rootzone}) + (\text{Depth}_{gravel} \times \text{AWC}_{gravel}) \quad (9)$$

The porosity and available water capacity of soils varies considerably, both spatially in the field and in the literature. The values chosen for the model (Table 4) are conservative.

Table 4 : Effective porosity and Available Water Capacity (Dunne & Leopold, 1978)

Soil Texture	Effective Porosity	Available Water Capacity (AWC)	Source
Bluemetal (20 mm recommended)	0.43	0.00	field measurements of 20 mm bluemetal from LCC Lismore Quarry
Coarse Sand	0.35	0.08	extrapolated from graph in Dunne & Leopold (1978)
Fine sand, Sandy loams	0.38	0.14	ditto
Loams, Clay loams, Silt	0.37	0.15	ditto
Clay (light, med, heavy)	0.34	0.13	ditto

Extra LAA with reed bed

To account for the extra hydraulic loading created when rain falls on an open reed bed, the equivalent extra areal depth of irrigation (a relatively small amount) over the LAA, is calculated as

$$\text{Reedbed_extra} = (\text{Reedbed_area} \times (\text{Throughflow} - \text{ET})) / \text{hydraulic_area} \quad (10)$$

where Reedbed_extra is a gain or loss (mm) spread over the hydraulic area of the LAA
 Reedbed_area is the calculated area of the reed bed open to rainfall and ET
 Throughflow is the rainfall reaching the reed bed (assumed for simplicity's sake to be the same as the throughflow for mown grass on the LAA)
 ET is the evapotranspiration from the reed bed (assumed to be the same as the ET from the grass growing on the LAA)

Water balance

The water balance used to calculate the LAA allows exceedence of the bucket's capacity on 5% of days (the wettest days in the rainfall record). The balance on the other 95% of days is accounted for in the following equation:

$$\text{Balance} = \text{Bucket}_{t-1} + \text{Throughflow} + \text{Irrigation_rate} + \text{Reedbed_extra} - \text{ET} - \text{Perc} \quad (11)$$

where Bucket_{t-1} is the areal depth of water in the bucket at the end of the previous day. The exceedence on the 5% of wettest days is represented in the following formula:

$$\text{Exceedence} = \max(0, \text{Balance} - \text{Bucket}_{sat}) \quad (12)$$

where Bucket_{sat} is the water depth (mm) when the bucket is full. The exceedence cannot be less than zero, so when the Balance is less than Bucket_{sat} the exceedence is equal to zero.

Bucket_{sat} is estimated from generic soil data in the literature (Dunne & Leopold 1978).

Thus the final value for the areal depth in the bucket is represented by

Bucket = Balance – Exceedence (13) where Bucket is the actual depth of water (mm) in the bucket.

Land application area is capped

Council has set a minimum cap of 15 m² per person for primary treated effluent and 10 m² per person for secondary treated effluent. This overwrites the calculated hydraulic area (or other limiting area) in cases where the LAA is very small.

The Nitrogen sub-model

Nitrogen processes

There are four main forms of N involved in wastewater disposal, and transformations between them are biologically mediated by different suites of micro-organisms. The main transformations may be summarized as follows:

Ammonification: Organic N (urea etc) → Ammonia N (NH₄⁺, NH₃ (gas))

Nitrification: Ammonia N → Nitrate N (NO₃⁻) (aerobic, during resting phase)

The main N losses during this process are as follows:

Denitrification: Nitrate + carbohydrate → N₂ gas + CO₂ (anaerobic, e.g. during loading phase)

Plant uptake: plants utilise ammonia N and nitrate N

Nitrogen equations

The equation to calculate the nitrogen area has remained the same since the last release of the model, shown conceptually in Figure 3. However, modifications have been made in relation to N areas within buffers.

$$\mathbf{Narea = 10000 \times (1 - Nlim / (Nload - Ndenit)) \times (Nload - Ndenit) / Nplant} \quad (14)$$

where Narea is the LAA based on TN loading

Nlim is the allowable TN export (kg/system.yr) out of the bucket

Nload is the TN production of the household (kg/yr), assuming none lost in primary treatment.

Ndenit is combined TN losses via denitrification during secondary treatment and in the soil (kg/yr)

Nplant is TN plant uptake rate (kg/ha.yr). Plants growing in the disposal bed take up N at varying rates but, as Lismore City Council encourages the use of mown grass, a default value of 200 kg/ha.yr for turf is adopted here (Martens, 1998).

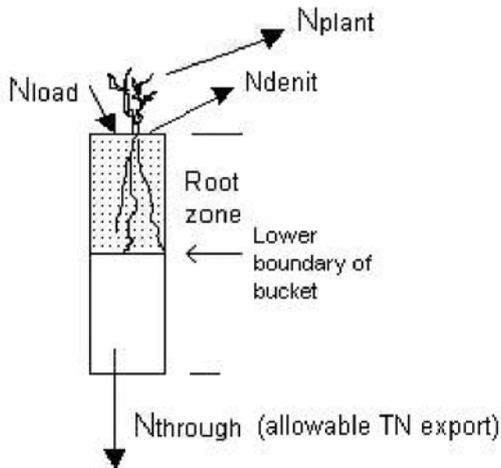


Figure 3. Conceptual nitrogen model

Expansion of these terms follows:

$$N_{lim} = N_{max} \times (1 - \exp(-kB)) \quad (15)$$

where N_{max} is the maximum allowed TN release into the environment (kg/system.yr, currently set at 15). This is an arbitrary value, but one that is roughly equal to an estimate of the TN loss to the environment in a traditional primary-only absorption trench from a household of four (allowing for some TN loss in the system). N_{max} is an asymptote. A value approaching 15 kg/system.yr is allowed on allotments of roughly 1 ha and larger.

k is a curvature factor (currently set at 3). This determines how quickly N_{max} is reduced as the allotment size is reduced below about 1 ha. The curviness of the function facilitates a smooth reduction from the asymptote N_{max} .

B is the allotment size, reduced from its actual value if the LAA is within the buffer to a stream or gully. The algorithm used to do this scales the allotment size proportionally to 600m² (representing a “very small” block size based on CVC experience) at a point halfway into the buffer.

$$B = 600 + (\text{Block} - 600) \times (\text{Buf} / 2 - \text{Dist_into_buf}) / (\text{Buf} / 2) \quad \text{Dist_into_buf} < \text{Buf} / 2 \quad (16) \text{ or}$$

$$B = 600 \times (\text{Buf} - \text{Dist_into_buf}) / (\text{Buf} / 2) \quad \text{Dist_into_buf} > \text{Buf} / 2$$

where Block is the actual allotment size

Buf is buffer width (e.g. 100 m for a stream)

Dist_into_buf is the distance measured from the edge of the buffer to the point in the LAA closest to the stream or gully

Thus, if a block size is 1600 m² and the LAA is 100 m from a stream, B will equal the actual allotment size of 1600 m². If the LAA is 50 m into the buffer (at buffer midpoint), then $B = 600$ m². If the LAA is 30 m into the buffer, then $B = 600 + (1600 - 600) \times (50 - 30) / 50 = 1000$ m². Ordinarily a LAA would not be allowed more than halfway into a buffer. Thus, in the case of a 100 m buffer to a waterway a LAA would not normally be allowed 60 m into the buffer (i.e. 40 m from the waterway). However, when the positioning of the LAA is unavoidably closer to the stream than the mid point of the buffer, then the second version of Eq. (16) may be used. *The purpose of reducing B within a buffer is to encourage increased TN removal by more effective secondary treatment.*

$$\text{Nload} = \text{No_persons} \times \text{Annual_loading_rate_per_person.} \quad (17)$$

The model assumes the N production (loading rate) is 4.2 kg/person.yr as measured locally (Davison *et al.*, 2002), a value in line with much international research. The ‘number of persons’ is proportionally adjusted when the wastewater stream is partial only (e.g. greywater only). It is assumed that greywater contains 30% of the TN load in the total wastewater stream (Table 2). The proportions of TN in greywater are allocated to kitchen, laundry and bathroom as follows, based on proportions cited by Witt *et al.* (1974), which are used cautiously. The adopted CVC values are adjusted as indicated, to preserve the proportion of greywater to blackwater (Table 5).

Table 5: Nitrogen production in various in-house fixtures

Toilet	Greywater			Total grey-water	Total	Source
	Kitchen	Laundry	Bathroom			
68%	15%	12%	5%	32%	100%	Witt <i>et al.</i> (1974)
70%	14% = 15/32 x 30	11% = 12/32 x 30	5% = 5/32 x 30	30%	100%	Adopted in LCC model

$$\text{Ndenit} = (1 - \text{Nloss_treatment}) \times (1 - \text{Nloss_soil}) \quad (18)$$

where Nloss_treatment is the TN reduction in the treatment system. Some of this may be loss due to ammonia volatilisation, though all the N losses in the treatment devices are lumped together here. Nloss_soil is the TN reduction in the soil of the LAA. A certain proportion of N added to the soil will be released into the atmosphere via denitrification. A conservative 0.2 (i.e. 20%) reduction is adopted in the model (Geary & Gardner 1996).

The Phosphorus sub-model

Phosphorus processes

There are three forms of phosphorus (P) involved in wastewater disposal. The main transformational sequence involves the slow hydrolysis of complex P-containing polymers to simpler forms:

Organic P (in nucleic acids etc) → Polyphosphates → Orthophosphates (plant available P)
(polyphosphates include triphosphates in detergents)

Plant available orthophosphates are a problem when entering waterways as they can stimulate toxic algal blooms. Generally P is not of major concern to the environment in the inland CVC areas due to the predominance of acidic P-adsorbing clay soils there. P pollution is more likely along the coastal areas where sand is the predominant soil type, since sand has very low P adsorbing capacity. Here careful attention to the P loading capabilities of the soil would be necessary.

The model primarily views the soil as a sink for P via adsorption, although a minor P removal mechanism is plant uptake.

The phosphorus sub-model has not changed since the last release of the model. A rearranged version of the Ryden and Pratt equation is used (Ryden & Pratt, 1980) to calculate the LAA based on phosphorus loading, shown diagrammatically in Figure 4.

$$P_{area} = (10000 \times P_{load}) / [(P_{sorp} \times (W - B)) / Design_life + P_{plant}] \quad (19)$$

where P_{area} is the LAA based on TP loading

P_{load} is the P load in the effluent (kg/yr)

P_{sorp} is P adsorbed in the soil per m of depth (kg/ha.m)

W is Water table depth or depth to bedrock (m)

B is Buffer to the water table (m), taken as 0.5m

P_{plant} is P removed by plants (kg/ha.yr), taken as 20 kg/ha.yr for turf or lawn (Myers *et al.* 1994).

$Design_life$ is the time of accumulation of P (yr) within the volume of soil bounded by the P area and the depth from the soil surface to the top boundary of the buffer-to-water-table B , taken as 50 years (i.e. it takes 50 years to fill this volume with P) as suggested by DLG *et al.*

(1998)

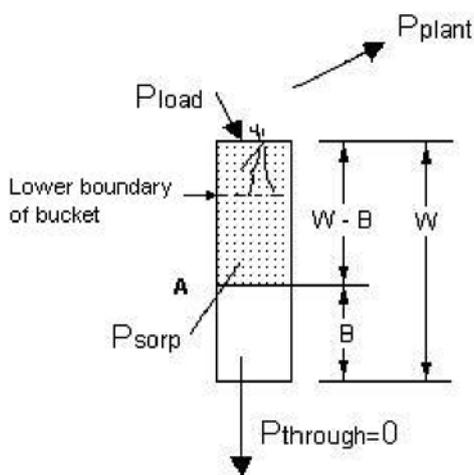


Figure 4. Conceptual phosphorus model

The model assumes the P production (loading rate) is 0.6 kg/person.yr (Geary & Gardner 1996). A recent local study determined P production to be 0.5 kg/person.yr (Davison *et al.* 2002). (Griffiths 1997) notes that detergents containing P have not been banned in Australia, and regards 0.88 kg/person.yr as typical of Australian domestic sewage. Hence 0.6 kg/person.yr was adopted as a conservative estimate for the local area. Table 6 was used to supply proportional outputs for the TP component of the check boxes. P production component percentages (Witt *et al.* 1974) from the USA are somewhat outdated and are therefore used with caution. The toilet component is probably significantly less than the 40% (100%-60%) inferred from Table 2 for blackwater. This reflects an era when detergents contained more phosphates, as noted above (Geary & Gardner 1996). Adopted LCC values are shown in Table 6, adjusted as indicated to preserve the proportion of greywater to blackwater (as shown in Table 2).

Table 6 : Phosphorous production in various in-house fixtures

Toilet	Greywater			Total grey-water	Total	Source
	Kitchen	Laundry	Bathroom			
13%	30%	55%	1%	87%	100%	Witt <i>et al.</i> , (1974)
40% (Table 2)	21% = 30/87 x 60	38% = 55/87 x 60	1% = 1/87 x 60	60% (Table 2)	100%	Adopted in LCC model

TP production is calculated in similar fashion to TN as follows. The ‘number of persons’ is proportionally adjusted when the wastewater stream is partial only (e.g. greywater only).

$$\text{Pload} = \text{No_persons} \times \text{Annual_loading_rate_per_person.} \quad (20)$$

Psorp is expressed as uptake per metre of depth in the soil below the disposal bed, P saturation being viewed as a front moving downwards. This soil acts as a P sink depending on the soil type chosen, which is the data associated with the list box marked “Morand code” on the model’s input page. Soil units (dp, ep etc) are from Morand (2001) *Soil Landscapes of the Woodburn 1:100,000 Sheet*, which list covers part of the CVC area. The two-letter codes in brackets under each soil type must be identified by referring to this reference.

The parameters Water Table Depth (W) and Buffer to Water Table (B) define the depth of soil into which P is adsorbed, assuming that sorption begins at the surface and progressively fills the soil downwards, moving as a front. B is usually set at 0.5m to allow for rises and falls in W. In instances where bedrock is relatively close to the surface W may be replaced by depth of bedrock.

Graphic representation of the land application area layout

On a separate worksheet **Designer** a graphic representation of the LAA in rectangular form is presented. This facility is only available for ETA beds. The layout may be altered by increasing or decreasing the number of ETA beds by means of a spinner button, and by altering the width of the beds and the separation between beds.

Step by step examples

The following examples apply the computer model to situations which might be encountered in the Clarence Valley area. In order to demonstrate the effect of block size most parameters will remain as presented in the first example. This is not to suggest that these are necessarily parameters common to most sites. Only soil tests can reveal the true nature of soil on a given site.

Example 1.

A 3 bedroom household on a 1 ha (10,000m²) block in Waterview Heights has the full wastewater complement, and its primary-treated (septic tank) effluent will be applied to an ETA bed on medium clay soil identified through bore hole samples. Roof harvesting provides all domestic water. The LAA is to be grassed, with an expected root zone depth of 150 mm and depth of trench beneath root zone of 150 mm.

After filling in the client's details and pressing the **Clear** button to reset the numerical defaults, follow these simple steps:

1. The Simplified (Or Casual User) box is checked.
2. Enter the Block size as **10000 m²** into the appropriate user-defined data entry cell.
3. The Buffer from the LAA is to a **stream** (chosen by activating the list box). This gives the default of >100 m (means 100m or more)
4. Water is from **Roof water harvesting** (140 L/person.day).
5. Number of Bedrooms is **3**. Enter this in the appropriate user-defined data entry cell.
6. The check boxes for Wastewater components are **all ticked**.
7. The soil type in 'Simplified' mode is **Medium to Heavy Clay**.
8. Phosphorus sorption is the default given (5780 kg/ha.m), unless otherwise justified.
9. Depth to water table is the default given **1 m** unless otherwise justified.
10. Depth to Bedrock is the default given **0.7m** unless otherwise justified.
11. Texture/structure of the soil beneath system is **Med to Hvy clays – weak struct/massive**.
12. Treatment System is **Primary only**.
13. Land application type is **ETA beds**.
14. Depth of soil above gravel layer (= root zone) is the default given (150 mm).
15. Depth of gravel layer is the default given (150 mm).
16. Click on the **Calc Area** button. Each of the hydraulic, nitrogen and phosphorus areas are reported. Required LAA, **347m²**, will be displayed.

The hydraulic area that results from this calculation is smaller than the N area. Repeat the example for a 5000 m² block. The result is the same for the hydraulic and phosphorus area whilst the N area has more than doubled to 173.3 m².

Example 2.

This example uses the same parameters as the first example, except that the block size is smaller.

- Make the following replacement:

Enter the Block size as **1000 m²**.

The LAA required is 561m². This is 56% of the entire block! On this constrained site secondary treatment or the use of a composting toilet will be required to reduce the N load to improve effluent water quality.

- Make the following replacement: The buffer from the LAA is to a **river** and is **50 m**.

This means the site is within the 100 m buffer at 50 m from permanent water. The resulting LAA is 632.5 m², an increase over the previous 561 m² because it is now in a more sensitive area, close to permanent water. This larger area may not be acceptable and highlights the need to use secondary treatment or a composting toilet.

- Make the following replacement:

The buffer from the LAA is to a **stream** and is >100 m (clear the user-defined value). We are now outside the buffer.

Treatment system is **Secondary: AWTS**

The resulting LAA is still 410.4 m², which may not be acceptable.

- Make the following change:

Treatment system is **Secondary: Reed bed – BOD 20mg/L**

The required LAA is now 347 m². Reed beds consistently reduce the N load by half or more when properly sized to allow at least 5 days residence time (Davison *et al.* 2002).

Another way of reducing the N load before land application is to remove the blackwater component from the wastewater stream by replacing the flush toilet with a composting toilet.

- Make the following changes:

Wastewater component check boxes are **ticked** except for **Toilet** which is **not ticked**; and Treatment System is **Primary only**.

The land application required is 208.2 m². This represents a major reduction in area compared to secondary treatment, but one which depends on the owner's acceptance of a composting toilet.

Example 3.

Again using mostly the same parameters as the first example, this example increases the block size to 4000m², a common average block size in some subdivisions within the Clarence Valley Council area. Increasing the block size also increases the acceptable rate of N release to the environment, thus reducing the level of constraint.

- Make the following changes:

Enter the Block size **4000 m²** into the appropriate data entry cell;

Wastewater component check boxes are **all ticked**, due to the presence of flush toilet; and Treatment system is **Primary only**.

The LAA required is 347m².

The inclusion of secondary treatment results in better space utilization.

- Make the following changes:

Treatment system is **Secondary: AWTS**

As Phosphorus is the limiting factor and AWTS have a limited Phosphorus removal capacity, the final area is unchanged at 347m².

Example 4.

This example uses the advanced user option in order to input a known set of soil parameters. It is based on the same example as above with known Gulmarrad (gu) – bundama group soil (Morand, 2001).

Click on the **Advanced (Consultants)** user info button to reset the defaults.

1. Block size is **4000 m²**
2. The buffer from the LAA is to a **stream**.
3. Water is from **Roof water harvesting**.
4. Water is from **Roof water harvesting** (140 L/person.day).
5. Number of Bedrooms is **3**. Enter this in the appropriate user-defined data entry cell.
6. The check boxes for Wastewater components are **all ticked**.
7. The soil type in ‘Advanced’ mode is **gu; all clay; bundama group**.
8. Phosphorus sorption is the default given (7780 kg/ha.m).
9. Depth to water table is the default given **1 m** unless otherwise justified.
10. Depth to Bedrock is the default given **0.7m** unless otherwise justified.
11. Texture/structure of the soil beneath system is **Med to Hvy clays – weak struct/massive**.
12. Treatment System is **Secondary AWTS**.
13. Land application type is **ETA beds**.
14. Depth of soil above gravel layer (= root zone) is the default given (150 mm).
15. Depth of gravel layer is the default given (150 mm).
16. Click on the **Calc Area** button. Each of the hydraulic, nitrogen and phosphorus areas are reported. Required LAA, **279m²**, will be displayed.

The minimum required LAA is 279 m².

By changing to the ‘Advanced’ user option the more exact soil parameters were able to be inputted into the model. In the case the **gu; all clay; bundama group** soil option has a greater Phosphorus sorption value than the **Med to Hvy Clay** option in the ‘Simplified’ option and therefore the limiting Phosphorus area is reduced

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