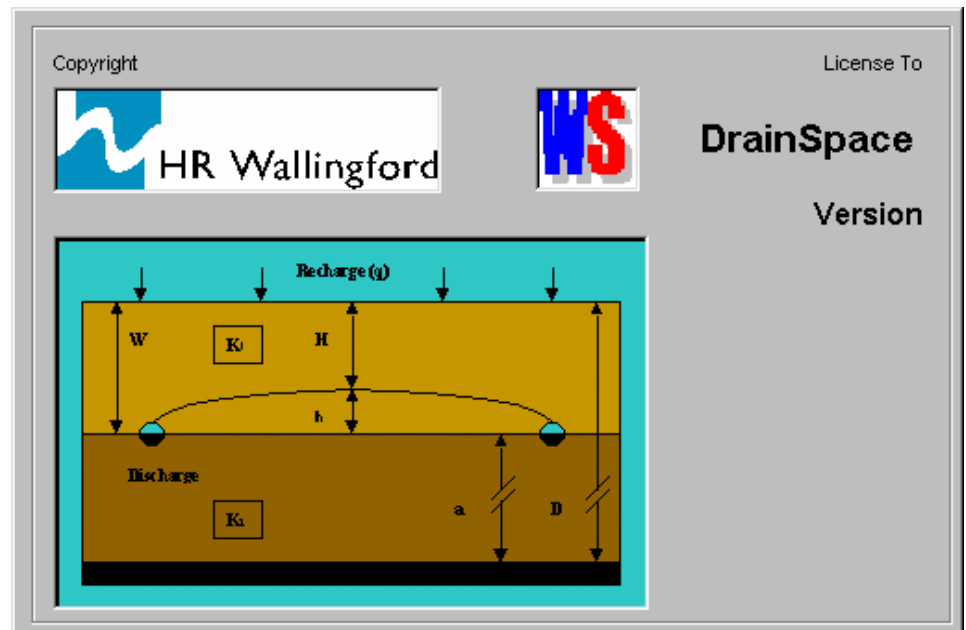


Appendix B - Design Modules

B.1 Introduction



WaSim contains 3 complementary design modules to aid sub-surface pipe drain design. These are outlined in the following sections.

Each of the 3 modules, for drain spacing, pipe sizing for field drains, and for collector drains, can be used separately from WaSim. However, the drain spacing module can also be run in advance of the WaSim software to help set the initial parameters for a realistic simulation.

B.2 Drain spacing

(Ref. Land Drainage. LK Smedema, DW Ryecroft. Batsford.1983)

Both Steady State (Hooghoudt) and Unsteady State (Glover-Dumm) equations are included in this module for calculating subsurface pipe drain spacing.

Hooghoudt Formula

10.0 Recharge (q) (mm/day)

0.50 Maximum Design Water Table Level (H) (m)

2.50 Field Drain Depth (W) (m)

8.00 Total Depth to Impermeable Layer (D) (m)

0.30 U value (m)

Glover Dumm Formula

5.00 Above Drain (K1) (m/day)

5.00 Below Drain (K2) (m/day)

100 User Defined Safety Factor (%)

Use relevant values from Glover Dumm formula tab

Accept Values Run Hooghoudt Close

Select the appropriate equation. To input data, use the slider bars and click the 'Accept Values' button to transfer the parameters to the results table.

The parameters for the Houghoudt equation are defined on the interactive diagram. When elements of the full sized picture are selected with the mouse, a description appears for a few seconds below the diagram.

Click the Run button to evaluate the drain spacing.

*Note: The user defined safety factor is a coefficient to decrease the spacing by the selected percentage.

Results from a few calculations are shown below. 'Intermediates' are values used by the Hooghoudt or Glover-Dumm equations, derived from the field measurements (input parameters).

Hooghoudt Results													
	Input Parameters								Intermediates		Results		
Run	q(mm/day)	K1(m/day)	K2(m/day)	H(m)	W(m)	D(m)	U(m)	S(%)	h(m)	a(m)	L(m)		
1	7.0	4.00	4.00	1.00	2.00	6.00	0.30	100	1.00	4.00	132.41		
2	10.0	5.00	5.00	1.50	2.00	6.00	0.30	100	0.50	4.00	80.81		
3	10.0	5.00	5.00	0.50	2.50	8.00	0.30	100	2.00	5.50	211.91		

Glover Dumm Results													
	Input Parameters								Intermediates			Results	
Run	T(days)	K(m/day)	P(%)	HO(m)	HT(m)	W(m)	D(m)	U(m)	S(%)	hO(m)	hT(m)	a(m)	L(m)
1	7	5.00	0.17	0.50	2.00	4.00	6.00	0.30	100	3.50	2.00	2.00	38.18
2	3	5.00	0.05	1.50	2.00	4.00	6.00	0.30	100	2.50	2.00	2.00	66.56
3	3	5.00	0.05	0.50	2.00	4.00	6.00	0.30	100	3.50	2.00	2.00	46.99

A few calculations will soon fill the results tables but ten calculations from each equation can be viewed simultaneously by clicking the 'View Results' button.

A summary of the equations used is presented below.

Hooghoudt Equation

The **Hooghoudt equation** is used when the flow is steady (the watertable is at a constant level).

The Hooghoudt equation uses a function, reduced depth (d_r), to replace the depth to the impermeable layer below the drain (a).

If the calculated drain spacing is not larger than the depth from the drainage base to the impermeable layer by a factor of 4 ($L > 4a$) then the calculation of the reduced depth (d_r) is not valid and the results from the equation should not be assumed accurate.

Hooghoudt equation:

$$q = \frac{(8K_2 d_r h + 4K_1 h^2)}{L^2} \text{ ----- B 1)}$$

or

$$L = \sqrt{(8K_2 d_r h + 4K_1 h^2) / q} \text{ ----- B 2)}$$

where,

L = drain spacing (m)

K_1 = weighted hydraulic conductivity above the drains (mm/hr)

K_2 = weighted hydraulic conductivity below the drains (mm/hr)

h = water table head above drain at midpoint between drains (m)

a = depth of barrier (impermeable layer) below drains (m)

d_r = reduced equivalent depth to impermeable layer (m)

q = drainage rate (mm/hr)

The equivalent depth (d_r) is calculated from one of the following equations:

$$d_r = \frac{a}{1 + (8a/pL) \ln(a/u)}; \text{ for } a/L < 0.25 \quad \text{----- B 3)a}$$

$$d_r = \frac{pL}{8[\ln(L/u)]}; \text{ for } a/L > 0.25 \quad \text{----- B 3)b}$$

u = wetted perimeter of the drain (m)

Glover-Dumm Equation

In the case of unsteady flow, a rise or fall in the watertable occurs as water is stored in or released from the soil. The **Glover-Dumm equation** can be used to estimate the drain spacing required to lower the watertable to a desired level in a given time period. By introducing Hooghoudt's reduced depth into the Glover-Dumm formulation, the resistance caused by the converging flow towards the drains is taken into account.

Unsteady state

Glover-Dumm equation:

$$L = p \left(\frac{K d_r t}{m} \right)^{\frac{1}{2}} \left(\ln 1.16 \frac{h_0}{h_t} \right)^{-\frac{1}{2}} \quad \text{----- B (4)}$$

where:

L = drain spacing

K = hydraulic conductivity (m/day)

d_r = reduced equivalent depth (m) to impermeable layer
(as in the Hooghoudt formulation)

t = time after instantaneous rise of the watertable

m = drainable pore space

h_0 = initial height of the watertable above drain level at time $t=0$

h_t = height of the watertable above drain level at time t

B.3 Pipe Sizing

Drain Design for Single Diameter Pipes Module

(Ref. Drainage Principles and Applications. ILRI Pub. 16, 1994)

The Manning Equation for pipe flow is used in this module.

$$Q = \frac{1}{n} A R^{\frac{2}{3}} s^{\frac{1}{2}} \text{----- B (5)}$$

where

- Q = flow rate (m³/s)
- n = Manning's roughness coefficient
- A = cross-sectional area (m²)
- s = hydraulic gradient
- R = hydraulic radius (m)
- P = wetted perimeter (m)

For full flowing pipes

$$R = \frac{d}{4}$$

where d is the diameter of the pipe

For Uniform Flow in full flowing pipes, Manning's equation becomes

$$Q = 0.312 \frac{1}{n} d^{2.67} s^{\frac{1}{2}} \text{----- B (6)}$$

This formula is used by the program to calculate any one of the following when the other two are known:

- minimum required pipe diameter
- hydraulic gradient
- discharge

Any of these parameters can be selected with the option buttons to the right of the parameter input sliders.

Non-Uniform Flow, Perforated pipes

For equal flows, the head loss in a perforated pipe (non-uniform flow) is 1/3 that in a closed pipe of similar diameter. For a field drain flowing full and for equal gradients s :

$$Q_{perf} = Q_{cl} \sqrt{3}$$

Or:

$$Q_{cl} = 0.58 Q_{perf} \text{----- B (7)}$$

and:

$$Q_{perf} = \frac{0.54}{n} d^{2.67} s^{\frac{1}{2}} \text{----- B (8)}$$

Where

Q_{perf} = discharge of a perforated pipe (non-uniform flow)

Q_{cl} = discharge of a closed wall pipe (uniform flow)

d = pipe diameter

n = Mannings roughness coefficient

s = hydraulic gradient

Discharge Calculator

Drainage Spacing (m) 50

Field Length (m) 250

Drainage Coefficient (mm/day) 5.0

Evaluate

Discharge (l/s)

Pipe Design Parameters

Discharge (l/s)

Pipe Inside Diameter (mm) 100

Hydraulic Gradient 0.0010

Roughness (n) 0.016

Choose parameter to be evaluated

Run

Field length and drainage spacing (from the Spacing for Field Drains module) can be entered into the discharge calculator to give a value for discharge.

Results are given for perforated field drains (non-uniform flow) and for collectors or transport pipelines.

Non-Uniform Flow Pipe Design Parameters (Draining Pipe Lines)				
Run	Discharge (l/s)	Pipe Diameter (mm)	Slope	Manning's n
1	1.32	100	0.0010	0.016
2	0.72	80	0.0010	0.016
3	0.72	100	0.0003	0.016

Uniform Flow Pipe Design Parameters (Transport Pipe Lines)				
Run	Discharge (l/s)	Pipe Diameter (mm)	Slope	Manning's n
1	0.76	100	0.0010	0.016
2	0.72	98	0.0010	0.016
3	0.72	100	0.0009	0.016

Drain Design for Collector Pipes

This module is used for determining the minimum diameter requirement for collector pipes in uniform flow. The Manning equation is used for evaluating the pipe-full diameter for each length of sub-collector required for each field drain added.

$$Q = 0.312 \frac{1}{n} d^{2.67} s^{\frac{1}{2}}$$

----- (as before)

where,

- Q = flow rate (m³/s)
 n = Manning's roughness coefficient
 s = hydraulic gradient
 d = diameter of the pipe

To determine a minimum diameter for a collector, click the 'Add Lateral' button, which allows details of flow from the incoming lateral, and basic parameters for the collector, to be input with the sliders.

Pipe Design Parameters

Drainage Spacing (m)

Drainage Coefficient (mm/day)

Hydraulic Gradient

Roughness (n)

Lateral Length (m)

To remove unwanted laterals, select a lateral or range of laterals and click 'Remove Lateral'. The 'Undo Remove' button can be used to replace laterals removed by mistake.

Uniform Flow Non-perforated Collector Drain Sizes						
Lateral Pipe Length (m)	Collector Pipe Length (m)	Collector Slope	Cumulative Area (ha.)	Cumulative Discharge (l/s)	Manning's n	Pipe Diameter (mm)
540	50	0.0010	2.700	2.694	0.0160	130.8
290	100	0.0010	5.600	5.588	0.0160	172.0
250	500	0.0010	18.100	17.962	0.0160	266.5
250	50	0.0010	19.350	19.187	0.0160	273.2

For small diameter pipes, savings in pipe cost which could be obtained by progressively increasing the pipe diameter at junctions working downstream, rather than using a single size over long distances, may not be justified because of higher organization and installation costs.

Safety factor

Over time the flow capacity of pipe drains will decrease because of sedimentation, chemical deposits or intrusion of roots.

There are various ways of incorporating safety factors to compensate for reduction in pipe capacity. A traditional method is to reduce the pipe discharge by a reduction factor, R , according to the following guidelines:

- For small diameter pipes (field drains, $d < 100$ mm), take 60% of the theoretical capacity ($R = 0.60$)
- For larger diameters (generally collectors, $d > 100$ mm), take 75% of the theoretical capacity ($R = 0.75$)

