Catch Drains Part 3: Grass-lined

DRAINAGE CONTROL TECHNIQUE

Low Gradient	✓	Velocity Control		Short Term	✓
Steep Gradient		Channel Lining		Medium-Long Term	✓
Outlet Control		Soil Treatment		Permanent	[1]

[1] The design of permanent catch drains requires consideration of issues not discussed within this fact sheet, such as maintenance requirements. This fact sheet should not be used for the design of permanent drains.

Symbol → CD →

Photo 9 – Grass-lined, parabolic drain

Photo 10 – Common erosion problem resulting from flow bypassing along up-slope edge of turf

Key Principles

1. Catch drains typically have standardised cross-sectional dimensions. Rather than uniquely sizing each catch drain to a given catchment, standard-sized drains are used based on a maximum allowable catchment area for a given rainfall intensity.
2. The **maximum** recommended spacing of catch drains down slopes (Table 3, *Part 1 – General information*) is based on the aim of avoiding rill erosion within the up-slope drainage slope. It should be noted that the **actual** spacing of catch drains down a given slope may need to be less than the specified maximum spacing if the soils are highly erosive soils, or if rilling begins to occur between two existing drains.
3. The critical design parameters are the spacing of the drains down a slope, the maximum allowable catchment area, the choice of lining material (e.g. earth, turf, rock or erosion control mats), and the required channel gradient.

Design Information

The following information must be read in association with the general information presented in *Part 1 – General information*. The following design tables specifically address grass-lined catch drains of specific dimensions.

The design procedure outlined within this fact sheet has been developed to provide a simplified approach suitable for appropriately trained persons involved in the regular design of temporary catch drains. The procedure is just **one** example of how catch drains can be designed. Designers experienced in hydraulic design can of course, design a catch drain using the general principles of open channel hydrologic/hydraulic as outlined in IECA (2008) Appendix A – *Construction site hydrology and hydraulics*.

Common Problems

Stormwater approaching the drain fails to enter the grass-lined section of the drain, but instead travels down the upper edge of the turf (Photo 10) causing rill erosion. This problem is usually only associated with turf lined drains. The problem can be avoided by ensuring an irregular (zigzag) upper edge of the turf.

If high flows occur during the first 2 or 3 weeks following placement of the turf, then erosion can occur along the joints between the turf strips. This can be prevented by placing the turf is a 'stretcher-bond' layout.

Catch drains not discharging to a stable outlet either causing erosion downstream of the outlet.

Special Requirements

The erosion-resistance of the local subsoils should be investigated before designing grass-lined drains.

Catch drains need to be appropriately stabilised (i.e. well anchored to the soil) within a specified period from the time of construction. In critical locations, turf needs to be anchored with wooden stakes, **not** metal pins or staples, which can rust and cause injury to pedestrian traffic.

Catch drain should drain to a suitable sediment trap if the diverted water is expected to contain sediment. 'Clean' water should divert around sediment traps.

The drain must have positive gradient along its full length to allow free drainage.

Sufficient space must be provided to allow necessary maintenance access.

Site Inspection

Check that the drain has a stable, positive grade along its length.

Check for a stable drain outlet.

Check if the associated flow diversion bank (if any) is free of damage, i.e. damage caused by construction traffic.

Check that the drain has adequate hydraulic capacity given the catchment area (general observations based on past experience).

Check if rill erosion is occurring within the catchment area up-slope of the drain. If rilling is occurring, then the lateral spacing of the drains will need to be reduced. However, some degree of rill erosion may be expected if recent storms exceeded the intensity of the nominated design storm.

Check for rilling along the up-slope edge of the turf/grass.

Inspect for evidence of water spilling out (overtopping) of the drain, or erosion down-slope of the drain.

Inspect for erosion along the bed (invert) of the drain. Investigate the reasons for any erosion before recommending solutions. Bed erosion can result from either excessive channel velocities, or an unstable outlet, which causes bed erosion (head-cut) to migrate up the channel.

Possible solutions to channel erosion include:

- reduce effective catchment area;
- increase channel width;
- increase channel roughness;
- stabilise the outlet.

Installation

1. Refer to approved plans for location, extent, and construction details. If there are questions or problems with the location, extent, or method of installation, contact the engineer or responsible on-site officer for assistance.
2. Ensure all necessary soil testing (e.g. soil pH, nutrient levels) and analysis has been completed, and required soil adjustments performed prior to planting.
3. Clear the location for the catch drain, clearing only what is needed to provide access for personnel and equipment for installation.
4. Remove roots, stumps, and other debris and dispose of them properly. Do not use debris to build the bank.
5. Grade the drain to the specified slope and form the associated embankment with compacted fill. Note that the drain invert must fall 10cm every 10m for each 1% of channel gradient.
6. Ensure the sides of the cut drain are no steeper than a 1.5:1 (H:V) slope and the embankment fill slopes no steeper than 2:1.

7. Ensure the completed drain has sufficient deep (as specified for the type of drain) measured from the drain invert to the top of the embankment. Where necessary, cut the drain slightly deeper than that specified on the plans such that the correct channel dimensions are achieved following placement of the turf.
8. Ensure the drain has a constant fall in the desired direction free of obstructions.
9. Turf should be used within 12-hours of delivery, otherwise ensure the turf is stored in conditions appropriate for the weather conditions (e.g. a shaded area).
10. Moistening the turf after it is unrolled will help maintain its viability.
11. Turf should be laid on a minimum 75mm bed of adequately fertilised topsoil. Rake the soil surface to break the crust just before laying the turf.
12. During the warmer months, lightly irrigate the soil immediately before laying the turf.
13. Ensure the turf is not laid on gravel, heavily compacted soils, or soils that have been recently treated with herbicides.
14. For wide drains and high velocity *chutes*, lay the first row of turf in a straight line diagonal to the direction of flow. Stagger subsequent rows in a brick-like (stretcher bond) pattern. The turf should not be stretched or overlapped. Use a knife or sharp spade to trim and fit irregularly shaped areas.
15. For narrow drains, lay the turf along the direction of the drain, ensuring, wherever practicable, that a longitudinal joint between two strips of turf is not positioned along the invert of the drain.
16. Ensure the turf extends up the sides of the drain at least 100mm above the elevation of the channel invert, or at least to a sufficient elevation to fully contain expected channel flow.
17. On channel gradients of 3:1(H:V) or steeper, or in situations where high flow velocities (i.e. velocity >1.5m/s) are likely within the first 2-weeks following placement, secure the individual turf strips with wooden or plastic pegs.
18. Ensure that intimate contact is achieved and maintained between the turf and the soil such that seepage flow beneath the turf is avoided.
19. Water until the soil is wet 100mm below the turf. Thereafter, watering should be sufficient to maintain and promote healthy growth.
20. Ensure the drain discharges to a stable outlet such that down-slope soil erosion will be prevented from occurring. Ensure the drain does not discharge to an unstable fill slope.

Maintenance

1. Inspect all catch drains at least weekly and after runoff-producing storm events and repair any slumps, bank damage, or loss of freeboard.
2. Ensure fill material or sediment is not partially blocking the drain. Where necessary, remove any deposited material to allow free drainage.
3. Dispose of any sediment or fill in a manner that will not create an erosion or pollution hazard.

Removal

1. When the soil disturbance above the catch drain is finished and the area is stabilised, the drain and any associated banks should be removed, unless it is to remain as a permanent drainage feature.
2. Dispose of any sediment or earth in a manner that will not create an erosion or pollution hazard.
3. Grade the area and smooth it out in preparation for stabilisation.
4. Stabilise the area by grassing or as specified within the approved plan.

Hydraulic design of grass-lined catch drains (using the Rational Method approach):

Step 1 Choose the preferred surface condition of the catch drain (i.e. grass-lined drain).

Step 2 Determine the allowable flow velocity (V_{allow}) using Table 17.

Step 3 Nominate the catch drain profile: parabolic or triangular (V-drain). Parabolic drains have a greater hydraulic capacity and are generally less susceptible to invert erosion, but can be slightly more time-consuming to construct.

Step 4 Choose a trial catch drain size (flow top width 'T', and depth 'Y') from Table 18 (parabolic drains), or Table 23 (triangular V-drains).

Ultimately this may require an iterative process where various drain sizes are tested for hydraulic capacity using the following design steps.

Step 5 Determine the required longitudinal gradient (S%) and Manning's roughness (n) for the catch drain using Tables 19 or 24, depending on the chosen drain profile. Note, this is the drain slope that will achieve the maximum hydraulic capacity given the nominated allowable flow velocity from Step 2.

Step 6 Determine the required *Average Recurrence Interval* (ARI) of the design storm for the given catch drain (i.e. 1 year, 2 year, 5 year, etc. – refer to Table 4.3.1 in Chapter 4, or Table A1 in Section A2 of Appendix A). Note, if a locally adopted design standard exists, then the ARI must be determined from that standard.

Step 7 Determine the appropriate *time of concentration* (t_c) for the catch drain (refer to Step 4 in IECA 2008, Appendix A, Section A2).

It is usually sufficient to assume a 5-minute time of concentration (conservative approach), otherwise use the locally adopted hydrologic procedures for determining the time of concentration, or the procedures presented in IECA (2008) Appendix A if no preferred local procedure exists.

Step 8 Given the design storm ARI, and duration (t_c), determine the *Average Rainfall Intensity* (I) for the catch drain (refer to Step 6 in Section A2 of Appendix A).

To determine the average rainfall intensity it will be necessary to obtain the relevant *Intensity-Frequency-Duration* (IFD) chart for the given site location.

Step 9 Determine the *maximum unit catchment area* (A*) of the catch drain using Tables 20 to 22, or Tables 25 to 27 depending on the chosen drain type and profile.

The maximum unit catchment area (A*) is the maximum allowable catchment area based on a coefficient of discharge of unity (i.e. C = 1.0).

Step 10 Determine the actual *Coefficient of Discharge* (C) for the catchment contributing runoff to the catch drain (refer to Step 3 in IECA 2008, Appendix A, Section A2).

Note, it will be necessary to first determine the *Coefficient of Discharge* for a 10 year storm (C_{10}), and then the *Frequency Factor* (F_Y) for the nominated design storm frequency from Table A7 in Step 3, Section A2 of Appendix A, such that:

$$C = C_{10} \cdot F_Y \leq 1.0$$

Step 11 Determine the maximum allowable catchment area (A) for the catch drain based on the *Coefficient of Discharge* (C) determined in Step 10:

$$A = (A^*)/C \quad \text{(hectares)}$$

Step 12 Determine the maximum allowable horizontal spacing of the catch drains down the slope from Table 3 (*Catch Drain, Part 1: General information*).

Step 13 If the desired catchment area of the catch drain (measured from the Erosion and Sediment Control Plan) is **greater** than the maximum allowable area determined in Step 11, that return to Step 4 and select a larger catch drain profile.

If the actual catchment area of the catch drain is **less** than the maximum allowable area determined in Step 11, then either return to Step 4 and select a smaller catch drain profile; or determine the minimum allowable drain slope (S_{min}) which is limited by the maximum allowable flow depth (y), and maximum allowable drain slope (S_{max}) which is limited by the maximum allowable flow velocity V_{allow}.

Explanation of the design philosophy adopted within this fact sheet:

Given the cross-sectional dimensions of a given catch drain (A & R), its surface roughness (n), gradient (S), and required freeboard, it is possible (using Manning's equation) to determine the hydraulic capacity (Q) of the drain, as presented in Equation 1.

Manning's equation: $$Q = \frac{1}{n}.A.R^{2/3}.S^{1/2} \quad \text{(Eqn 1)}$$

where: A = cross-sectional flow area of the catch drain

The Rational Method (Equation 2) can be rearrange to form Equation 3:

$$Q = (C.I.A)/360 \quad \text{(Eqn 2)}$$

$$A.C = 360(Q / I) \quad \text{(Eqn 3)}$$

where: A = catchment area (ha) of the catch drain (**not** the cross-sectional area of the drain)

If we define a new term called 'the unit catchment area' (A*) as the effective catchment area based on an **assumed** coefficient of discharge of unity (i.e. C = 1.0), then:

Maximum unit catchment area: $$A^* = 360(Q / I) \quad \text{(Eqn 4)}$$

The relationship between flow velocity (V) and channel slope (S) is given by a modification of the Manning's equation (Equation 5):

$$V = \frac{1}{n}.R^{2/3}.S^{1/2} \quad \text{(Eqn 5)}$$

For a given catch drain profile (represented by the hydraulic radius, R), and surface lining (represented by the Manning's roughness, n) we can determine the required drain slope (S) for a given allowable flow velocity. This information is presented in Tables 19 and 24. It is noted that at this channel slope, the maximum allowable flow velocity (V_{allow}) will be achieved when the channel is flowing at the maximum allowable flow depth (Y).

Also, for a given catch drain cross-sectional area (A), hydraulic radius (R), and maximum allowable flow velocity (V), we can determine the maximum allowable discharge (Q) from Equation 1. With this discharge, and the nominated design rainfall intensity (I), we can determine the maximum unit catchment area (A*) from Equation 4. This information is presented in Tables 20 to 22 for parabolic drains, and Tables 25 to 27 for drains with a triangular profile.

This means Tables 20 to 22 and 25 to 27 are independent of location, and thus can be used anywhere in the world. Rainfall intensity, I (mm/hr) being the only parameter that is location specific.

In order to determine the maximum allowable catchment area (A), it is necessary to determine the **actual** coefficient of discharge (C) for the adopted storm frequency (ARI), and catchment conditions (i.e. soil porosity). The maximum allowable catchment area (A) is determined from Equation 6.

Maximum allowable catchment area: $$A = A^*/C \quad \text{(Eqn 6)}$$

Since the coefficient of discharge is always assumed to be less than or equal to unity, the maximum allowable catchment area (A) cannot exceed the maximum unit catchment area (A*).

If the actual catchment area is less than the calculated maximum catchment area (A) from Equation 6, then the catch drain can be constructed at a range of channel gradients such that:

$$S_{min} < S < S_{max}$$

where:

- S_{min} can be determined from Manning's equation based on the catch drain flowing full, but at a channel-full velocity less than the maximum allowable flow velocity;
- S_{max} can be determined from Manning's equation based on the catch drain flowing partially full, and at a velocity equal to the maximum allowable flow velocity.

Design example: Grass-lined catch drain

Design a temporary (< 24 months) grass-lined catch drain cut into a loam soil in Townsville with a desired length of 150m, catchment area of 1.0ha, and an average catchment land slope of 5%. The catch drain will be used to divert 'clean' water around a soil disturbance. The catchment consists of undisturbed, well-grassed, land, and the 'time of concentration' (t_c) for the catchment is known to be 13 minutes.

Step 1 A grass-lined drain has been nominated.

Step 2 Assuming the drain is turfed (i.e. 100% grass cover) and the loam soil has a low to moderate erosion potential, nominate an allowable flow velocity (V_{allow}) of 2.0m/s as a first trial from Table 17 (it is noted that the slope of the drain is currently unknown).

Step 3 Choose a triangular drain profile.

Step 4 Initially try a Type-BV catch drain with dimensions: T = 1.8m, Y = 0.3m.

Step 5 Determine the required longitudinal gradient (S) and Manning's roughness (n) from Table 23 as S = 8.3%, and n = 0.039 for a Type-BV drain based on an allowable flow velocity, V_{allow} = 2.0m/s.

Step 6 Nominate a 1 in 5 year ARI design storm from Table 4.3.1 (Chapter 4).

Step 7 The catchment time of concentration (t_c) is given as 13 minutes.

Step 8 Determine the average rainfall intensity: I = 140mm/hr for Townsville from Table A11 (Appendix A) for ARI = 5-year, and t_c = 13 minutes.

Step 9 Determine the maximum allowable unit catchment area as A* = 1.389ha from Table 26, given V = 2.0m/s, and I = 140mm/hr.

Step 10 Determine the coefficient of discharge (C_Y):

Given the catch drain's catchment area is open, undisturbed grass with medium permeability, 100% pervious surface area, and given that Townsville's 10 minute, 1-year rainfall intensity (${}^{1}I_{10}$) is 91.9mm/hr, the 10-year coefficient of discharge, C_{10} = 0.70 from Table A5 (Appendix A – *Construction site hydrology and hydraulics*).

Determine the frequency factor, F_Y = 0.95 for the 1 in 5-year ARI storm from Table A7 (Appendix A).

Calculate the effective coefficient of discharge (C) for the 1 in 5-year event using Equation A4 (Appendix A):

$$C = C_5 = F_Y . C_{10} = 0.95 \times 0.70 = 0.665 \leq 1.0 \text{ (OK)}$$

Step 11 Calculate the maximum allowable catchment area (A) for the catch drain:

$$A = (A^*)/C = 1.389/0.665 = 2.089\text{ha}$$

Thus the maximum allowable catchment area is greater than the actual catchment area of 1.0ha, OK.

Step 12 Because this catch drain is being used to collect and divert 'clean' water from an undisturbed catchment there is no need (in this case) to determine the maximum allowable spacing of the catch drains down the catchment slope.

So, a Type-BV catch drain formed at a gradient of 8.3% will have a flow capacity significantly greater than is required for the specified 1.0ha catchment. At this point in the analysis we have the following options:

(i) stay with the current design (Type-BV, 8.3% grade, grass-lined);
(ii) stay with Type-BV drain, but calculate a suitable range of channel gradients;
(iii) try a smaller, Type-AV catch drain, but this may require a steeper grade.

Step 5a For the purpose of this example, option (ii) will be chosen

Given that the actual catchment area is significantly less than the maximum allowable catchment area, the catch drain can be constructed at:

- a flatter gradient (S_{min} < 8.3%) limited by the maximum flow depth of 0.3m; or
- a steeper gradient (S_{max} > 8.3%) limited by the allowable velocity of 0.6m/s.

To determined flattest allowable gradient for this catch drain, first calculate the design 1 in 5-year flow at the end of the 150m long catch drain.

$$Q = C\ I\ A/360 = (0.665 \times 140 \times 1.0)/360 = 0.259 m^3/s$$

The **flattest** longitudinal gradient of the catch drain can be determined from the Manning's equation (Equation A16 in IECA, 2008, Appendix A); where the flow top width (T) is 1.8m, and the flow depth (Y) is 0.3m.

However, due to the lower flow velocity, it would be expected that the Manning's roughness value (n) for a grass-lined drain would slightly increase from the value presented in Table 29. As a first guess it should be OK to assume that Manning's roughness remains close to n = 0.039 determined in Step 5, thus:

$$Q = 0.259 = (1/n).A.R^{2/3}.S^{1/2} = (1/0.039)(0.270)(0.142)^{2/3}.S^{1/2}$$

$$S_{min} = 1.88\%$$

Note, in the above equation, the term 'A' is the cross-sectional area of the catch drain at a depth of y = 0.3m (determined from Table 22), **not** the catchment area! Also, 'R' is the hydraulic radius for the drain flowing full (Y = 0.3m) which is also provided in Table 22.

The **steepest** longitudinal gradient of the catch drain can also be determined from Manning's equation (Equation A16 in Appendix A); however, in this case the drain will be flowing partially full with a flow top width (T) less than 1.8m, and the flow depth (y) less than 0.3m. *(Note, the drain would still be constructed with the same standard overall physical dimensions specified for all Type-BV catch drains.)*

Now, for a triangular Type-BV drain the numerical relationship between the flow top width (T) and the flow depth (y) is given by the following equation (Table 4):

$$y = 0.1667(T)$$

and the cross sectional area of flow (A) is given by (Table A30a, Appendix A):

$$A = 0.5(T.y) = 0.0833\ T^2 = Q/V = 0.259/2.0 = 0.129 m^2$$

Therefore, the flow top width, T = 1.246m; the flow depth, y = 0.208m; and the hydraulic radius (R) can be determined from (Table A29b, Appendix A):

$$R = \frac{T.y}{2\sqrt{(T^2 + 4y^2)}} = \frac{1.246 \times 0.208}{2\sqrt{(1.246^2 + 4(0.208)^2}} = 0.098m$$

The maximum catch drain slope is given by rearranging the Manning's equation:

$$S(\%) = 100(V^2 . n^2)/R^{4/3} = 100 \times (2.0^2 \times 0.039^2)/0.098^{4/3} = 13.38\%$$

Therefore, the Type-BV catch drain can be constructed at any longitudinal gradient between 1.88% (maximum flow depth) and 13.38% (maximum flow velocity), and still provide the required hydraulic capacity for the 1 in 5 year design storm. It is noted that constructing the drain at the steeper gradient will result in a construction site with maximum drainage capacity.

Table 17 – Allowable flow velocity (m/s) for grass-lined drains [1]

Percentage grass cover	Gradient of catch drain (%)									
	1	2	3	4	5	6	8	10	15	20
70% [2]	2.0	1.8	1.7	1.6	1.6	1.5	1.5	1.4	1.3	1.3
100% [3]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.8	1.7
Poor soils [4]	1.5	1.4	1.3	1.2	1.2	1.1	1.1	1.1	1.0	0.9

[1] Maximum allowable flow velocity limited to 2.0m/s for temporary catch drains due to high risk of poor grass-root development due to the expected short plant establishment time (even when turf is used).

[2] 70% cover would be typical for most grasses established by seed, but only when there is sufficient plant establishment time prior to commissioning the drain (however, this is not typical on most construction sites).

[3] 100% cover is typical for most newly established, turf-lined catch drains.

[4] "Poor soils" refers to the soil's high erosion potential, such as dispersive clays (Emerson Class 1 and 2) such as sodic, yellow and red soils. Unstable, dispersible clayey sands and sandy clays, such as yellow and grey massive earths formed on sandstones and some granites. Highly erodible soils may include: lithosols, alluvials, podzols, siliceous sands, soloths, solodized solonetz, grey podzolics, some black earths, fine surface texture-contrast soils, and Soil Groups ML and CL.

Table 18 – Dimensions of standard parabolic catch drains

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-A	1.0m	0.15m	1.6m	0.30m	0.094m	0.100m^2
Type-B	1.8m	0.30m	2.4m	0.45m	0.186m	0.360m^2
Type-C	3.0m	0.50m	3.6m	0.65m	0.310m	1.000m^2

Table 19 – Manning's roughness and required longitudinal gradient (%) for (50–150mm) grass-lined, parabolic cross-section catch drains

Grass-lined channel, 50 to 150mm blade length	Allowable flow velocity along catch drain (m/s) based on type of grass and percentage cover [1]								
	1.0	1.2	1.4	1.5	1.6	1.8	2.0	2.2 [2]	2.5 [2]
	Type-A catch drain: flow width (T) = 1.0 m and flow depth (Y) = 0.15 m								
Manning's roughness (n)	0.057	0.053	0.050	0.048	0.047	0.045	0.044	0.042	0.040
Drain slope (%)	7.5	9.3	11.2	12.2	13.3	15.4	17.7	20.0	23.7
	Type-B catch drain: flow width (T) = 1.8 m and flow depth (Y) = 0.3 m								
Manning's roughness (n)	0.046	0.043	0.041	0.040	0.040	0.038	0.037	0.036	0.035
Drain slope (%)	2.01	2.56	3.15	3.47	3.79	4.46	5.18	5.93	7.12
	Type-C catch drain: flow width (T) = 3.0 m and flow depth (Y) = 0.5 m								
Manning's roughness (n)	0.041	0.039	0.037	0.037	0.036	0.035	0.034	0.033	0.032
Drain slope (%)	0.80	1.04	1.30	1.43	1.58	1.87	2.19	2.52	3.05

[1] The allowable velocity for grass-lined channels can be determined from Table A28 of IECA (2008) Appendix A – *Construction site hydrology and hydraulics.* Typically, an allowable flow velocity of around 1.5 to 2.0m/s is used.

[2] Allowable flow velocities of 2.2 and 2.5m/s would only be acceptable for well-established catch drains with 100% grass cover on good, erosion-resistant soils.

Table 20 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-A Catch Drain: Parabolic cross section										
Dimensions:			Flow top width = 1.0 m				Flow depth = 0.15 m			
Rainfall intensity (mm/hr)	Allowable flow velocity along catch drain (m/s)									
	1.0	1.2	1.4	1.5	1.6	1.8	2.0	2.2	2.5	3.0
15	2.400	2.880	3.360	3.600	3.840	4.320	4.800	5.280	6.000	7.200
20	1.800	2.160	2.520	2.700	2.880	3.240	3.600	3.960	4.500	5.400
25	1.440	1.728	2.016	2.160	2.304	2.592	2.880	3.168	3.600	4.320
30	1.200	1.440	1.680	1.800	1.920	2.160	2.400	2.640	3.000	3.600
35	1.029	1.234	1.440	1.543	1.646	1.851	2.057	2.263	2.571	3.086
40	0.900	1.080	1.260	1.350	1.440	1.620	1.800	1.980	2.250	2.700
45	0.800	0.960	1.120	1.200	1.280	1.440	1.600	1.760	2.000	2.400
50	0.720	0.864	1.008	1.080	1.152	1.296	1.440	1.584	1.800	2.160
55	0.655	0.785	0.916	0.982	1.047	1.178	1.309	1.440	1.636	1.964
60	0.600	0.720	0.840	0.900	0.960	1.080	1.200	1.320	1.500	1.800
65	0.554	0.665	0.775	0.831	0.886	0.997	1.108	1.218	1.385	1.662
70	0.514	0.617	0.720	0.771	0.823	0.926	1.029	1.131	1.286	1.543
75	0.480	0.576	0.672	0.720	0.768	0.864	0.960	1.056	1.200	1.440
80	0.450	0.540	0.630	0.675	0.720	0.810	0.900	0.990	1.125	1.350
85	0.424	0.508	0.593	0.635	0.678	0.762	0.847	0.932	1.059	1.271
90	0.400	0.480	0.560	0.600	0.640	0.720	0.800	0.880	1.000	1.200
95	0.379	0.455	0.531	0.568	0.606	0.682	0.758	0.834	0.947	1.137
100	0.360	0.432	0.504	0.540	0.576	0.648	0.720	0.792	0.900	1.080
105	0.343	0.411	0.480	0.514	0.549	0.617	0.686	0.754	0.857	1.029
110	0.327	0.393	0.458	0.491	0.524	0.589	0.655	0.720	0.818	0.982
115	0.313	0.376	0.438	0.470	0.501	0.563	0.626	0.689	0.783	0.939
120	0.300	0.360	0.420	0.450	0.480	0.540	0.600	0.660	0.750	0.900
125	0.288	0.346	0.403	0.432	0.461	0.518	0.576	0.634	0.720	0.864
130	0.277	0.332	0.388	0.415	0.443	0.498	0.554	0.609	0.692	0.831
135	0.267	0.320	0.373	0.400	0.427	0.480	0.533	0.587	0.667	0.800
140	0.257	0.309	0.360	0.386	0.411	0.463	0.514	0.566	0.643	0.771
145	0.248	0.298	0.348	0.372	0.397	0.447	0.497	0.546	0.621	0.745
150	0.240	0.288	0.336	0.360	0.384	0.432	0.480	0.528	0.600	0.720
155	0.232	0.279	0.325	0.348	0.372	0.418	0.465	0.511	0.581	0.697
160	0.225	0.270	0.315	0.338	0.360	0.405	0.450	0.495	0.563	0.675
165	0.218	0.262	0.305	0.327	0.349	0.393	0.436	0.480	0.545	0.655
170	0.212	0.254	0.296	0.318	0.339	0.381	0.424	0.466	0.529	0.635
175	0.206	0.247	0.288	0.309	0.329	0.370	0.411	0.453	0.514	0.617
180	0.200	0.240	0.280	0.300	0.320	0.360	0.400	0.440	0.500	0.600
185	0.195	0.234	0.272	0.292	0.311	0.350	0.389	0.428	0.486	0.584
190	0.189	0.227	0.265	0.284	0.303	0.341	0.379	0.417	0.474	0.568
200	0.180	0.216	0.252	0.270	0.288	0.324	0.360	0.396	0.450	0.540
210	0.171	0.206	0.240	0.257	0.274	0.309	0.343	0.377	0.429	0.514
220	0.164	0.196	0.229	0.245	0.262	0.295	0.327	0.360	0.409	0.491
230	0.157	0.188	0.219	0.235	0.250	0.282	0.313	0.344	0.391	0.470
240	0.150	0.180	0.210	0.225	0.240	0.270	0.300	0.330	0.375	0.450
250	0.144	0.173	0.202	0.216	0.230	0.259	0.288	0.317	0.360	0.432
Q (m^3/s)	0.100	0.120	0.140	0.150	0.160	0.180	0.200	0.220	0.250	0.300

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 19).

Table 21 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-B Catch Drain: Parabolic cross section

Dimensions:				Flow top width = 1.8 m				Flow depth = 0.3 m		
Rainfall intensity (mm/hr)	Allowable flow velocity along catch drain (m/s)									
	1.0	**1.2**	**1.4**	**1.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	**3.0**
15	8.640	10.368	12.096	12.960	13.824	15.552	17.280	19.008	21.600	25.920
20	6.480	7.776	9.072	9.720	10.368	11.664	12.960	14.256	16.200	19.440
25	5.184	6.221	7.258	7.776	8.294	9.331	10.368	11.405	12.960	15.552
30	4.320	5.184	6.048	6.480	6.912	7.776	8.640	9.504	10.800	12.960
35	3.703	4.443	5.184	5.554	5.925	6.665	7.406	8.146	9.257	11.109
40	3.240	3.888	4.536	4.860	5.184	5.832	6.480	7.128	8.100	9.720
45	2.880	3.456	4.032	4.320	4.608	5.184	5.760	6.336	7.200	8.640
50	2.592	3.110	3.629	3.888	4.147	4.666	5.184	5.702	6.480	7.776
55	2.356	2.828	3.299	3.535	3.770	4.241	4.713	5.184	5.891	7.069
60	2.160	2.592	3.024	3.240	3.456	3.888	4.320	4.752	5.400	6.480
65	1.994	2.393	2.791	2.991	3.190	3.589	3.988	4.386	4.985	5.982
70	1.851	2.222	2.592	2.777	2.962	3.333	3.703	4.073	4.629	5.554
75	1.728	2.074	2.419	2.592	2.765	3.110	3.456	3.802	4.320	5.184
80	1.620	1.944	2.268	2.430	2.592	2.916	3.240	3.564	4.050	4.860
85	1.525	1.830	2.135	2.287	2.440	2.744	3.049	3.354	3.812	4.574
90	1.440	1.728	2.016	2.160	2.304	2.592	2.880	3.168	3.600	4.320
95	1.364	1.637	1.910	2.046	2.183	2.456	2.728	3.001	3.411	4.093
100	1.296	1.555	1.814	1.944	2.074	2.333	2.592	2.851	3.240	3.888
105	1.234	1.481	1.728	1.851	1.975	2.222	2.469	2.715	3.086	3.703
110	1.178	1.414	1.649	1.767	1.885	2.121	2.356	2.592	2.945	3.535
115	1.127	1.352	1.578	1.690	1.803	2.029	2.254	2.479	2.817	3.381
120	1.080	1.296	1.512	1.620	1.728	1.944	2.160	2.376	2.700	3.240
125	1.037	1.244	1.452	1.555	1.659	1.866	2.074	2.281	2.592	3.110
130	0.997	1.196	1.396	1.495	1.595	1.794	1.994	2.193	2.492	2.991
135	0.960	1.152	1.344	1.440	1.536	1.728	1.920	2.112	2.400	2.880
140	0.926	1.111	1.296	1.389	1.481	1.666	1.851	2.037	2.314	2.777
145	0.894	1.073	1.251	1.341	1.430	1.609	1.788	1.966	2.234	2.681
150	0.864	1.037	1.210	1.296	1.382	1.555	1.728	1.901	2.160	2.592
155	0.836	1.003	1.171	1.254	1.338	1.505	1.672	1.839	2.090	2.508
160	0.810	0.972	1.134	1.215	1.296	1.458	1.620	1.782	2.025	2.430
165	0.785	0.943	1.100	1.178	1.257	1.414	1.571	1.728	1.964	2.356
170	0.762	0.915	1.067	1.144	1.220	1.372	1.525	1.677	1.906	2.287
175	0.741	0.889	1.037	1.111	1.185	1.333	1.481	1.629	1.851	2.222
180	0.720	0.864	1.008	1.080	1.152	1.296	1.440	1.584	1.800	2.160
185	0.701	0.841	0.981	1.051	1.121	1.261	1.401	1.541	1.751	2.102
190	0.682	0.819	0.955	1.023	1.091	1.228	1.364	1.501	1.705	2.046
200	0.648	0.778	0.907	0.972	1.037	1.166	1.296	1.426	1.620	1.944
210	0.617	0.741	0.864	0.926	0.987	1.111	1.234	1.358	1.543	1.851
220	0.589	0.707	0.825	0.884	0.943	1.060	1.178	1.296	1.473	1.767
230	0.563	0.676	0.789	0.845	0.902	1.014	1.127	1.240	1.409	1.690
240	0.540	0.648	0.756	0.810	0.864	0.972	1.080	1.188	1.350	1.620
250	0.518	0.622	0.726	0.778	0.829	0.933	1.037	1.140	1.296	1.555
Q (m^3/s)	**0.360**	**0.432**	**0.504**	**0.540**	**0.576**	**0.648**	**0.720**	**0.792**	**0.900**	**1.080**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 19).

Table 22 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-C Catch Drain: Parabolic cross section										
Dimensions:			Flow top width = 3.0 m				Flow depth = 0.5 m			
Rainfall intensity (mm/hr)	Allowable flow velocity along catch drain (m/s)									
	1.0	1.2	1.4	1.5	1.6	1.8	2.0	2.2	2.5	3.0
15	24.00	28.80	33.60	36.00	38.40	43.20	48.00	52.80	60.00	72.00
20	18.00	21.60	25.20	27.00	28.80	32.40	36.00	39.60	45.00	54.00
25	14.40	17.28	20.16	21.60	23.04	25.92	28.80	31.68	36.00	43.20
30	12.00	14.40	16.80	18.00	19.20	21.60	24.00	26.40	30.00	36.00
35	10.29	12.34	14.40	15.43	16.46	18.51	20.57	22.63	25.71	30.86
40	9.00	10.80	12.60	13.50	14.40	16.20	18.00	19.80	22.50	27.00
45	8.00	9.60	11.20	12.00	12.80	14.40	16.00	17.60	20.00	24.00
50	7.20	8.64	10.08	10.80	11.52	12.96	14.40	15.84	18.00	21.60
55	6.55	7.85	9.16	9.82	10.47	11.78	13.09	14.40	16.36	19.64
60	6.00	7.20	8.40	9.00	9.60	10.80	12.00	13.20	15.00	18.00
65	5.54	6.65	7.75	8.31	8.86	9.97	11.08	12.18	13.85	16.62
70	5.14	6.17	7.20	7.71	8.23	9.26	10.29	11.31	12.86	15.43
75	4.80	5.76	6.72	7.20	7.68	8.64	9.60	10.56	12.00	14.40
80	4.50	5.40	6.30	6.75	7.20	8.10	9.00	9.90	11.25	13.50
85	4.24	5.08	5.93	6.35	6.78	7.62	8.47	9.32	10.59	12.71
90	4.00	4.80	5.60	6.00	6.40	7.20	8.00	8.80	10.00	12.00
95	3.79	4.55	5.31	5.68	6.06	6.82	7.58	8.34	9.47	11.37
100	3.60	4.32	5.04	5.40	5.76	6.48	7.20	7.92	9.00	10.80
105	3.43	4.11	4.80	5.14	5.49	6.17	6.86	7.54	8.57	10.29
110	3.27	3.93	4.58	4.91	5.24	5.89	6.55	7.20	8.18	9.82
115	3.13	3.76	4.38	4.70	5.01	5.63	6.26	6.89	7.83	9.39
120	3.00	3.60	4.20	4.50	4.80	5.40	6.00	6.60	7.50	9.00
125	2.88	3.46	4.03	4.32	4.61	5.18	5.76	6.34	7.20	8.64
130	2.77	3.32	3.88	4.15	4.43	4.98	5.54	6.09	6.92	8.31
135	2.67	3.20	3.73	4.00	4.27	4.80	5.33	5.87	6.67	8.00
140	2.57	3.09	3.60	3.86	4.11	4.63	5.14	5.66	6.43	7.71
145	2.48	2.98	3.48	3.72	3.97	4.47	4.97	5.46	6.21	7.45
150	2.40	2.88	3.36	3.60	3.84	4.32	4.80	5.28	6.00	7.20
155	2.32	2.79	3.25	3.48	3.72	4.18	4.65	5.11	5.81	6.97
160	2.25	2.70	3.15	3.38	3.60	4.05	4.50	4.95	5.63	6.75
165	2.18	2.62	3.05	3.27	3.49	3.93	4.36	4.80	5.45	6.55
170	2.12	2.54	2.96	3.18	3.39	3.81	4.24	4.66	5.29	6.35
175	2.06	2.47	2.88	3.09	3.29	3.70	4.11	4.53	5.14	6.17
180	2.00	2.40	2.80	3.00	3.20	3.60	4.00	4.40	5.00	6.00
185	1.95	2.34	2.72	2.92	3.11	3.50	3.89	4.28	4.86	5.84
190	1.89	2.27	2.65	2.84	3.03	3.41	3.79	4.17	4.74	5.68
200	1.80	2.16	2.52	2.70	2.88	3.24	3.60	3.96	4.50	5.40
210	1.71	2.06	2.40	2.57	2.74	3.09	3.43	3.77	4.29	5.14
220	1.64	1.96	2.29	2.45	2.62	2.95	3.27	3.60	4.09	4.91
230	1.57	1.88	2.19	2.35	2.50	2.82	3.13	3.44	3.91	4.70
240	1.50	1.80	2.10	2.25	2.40	2.70	3.00	3.30	3.75	4.50
250	1.44	1.73	2.02	2.16	2.30	2.59	2.88	3.17	3.60	4.32
Q (m^3/s)	**1.000**	**1.200**	**1.400**	**1.500**	**1.600**	**1.800**	**2.000**	**2.200**	**2.500**	**3.000**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 19).

Table 23 – Dimensions of standard triangular V-drains

Catch drain type	Max top width of flow (T)	Maximum flow depth (y)	Top width of formed drain	Depth of formed drain	Hyd. rad. (R) at max flow depth	Area (A) at max flow depth
Type-AV	1.0m	0.15m	2.0m	0.30m	0.072m	0.075m^2
Type-BV	1.8m	0.30m	2.7m	0.45m	0.142m	0.270m^2
Type-CV	3.0m	0.50m	3.9m	0.65m	0.237m	0.750m^2

Table 24 – Manning's roughness and required longitudinal gradient (%) for (50–150mm) grass-lined, triangular cross-section V-drains

Grass-lined channel, 50 to 150mm blade length	Allowable flow velocity along catch drain (m/s) based on type of grass and percentage cover [1]								
	1.0	**1.2**	**1.4**	**1.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**
	Type-AV catch drain: flow width (T) = 1.0 m and flow depth (Y) = 0.15 m								
Manning's roughness (n)	0.063	0.058	0.054	0.053	0.051	0.049	0.047	0.045	0.043
Drain slope (%)	13.2	16.2	19.4	21.0	22.7	26.2	29.8	33.5	39.4
	Type-BV catch drain: flow width (T) = 1.8 m and flow depth (Y) = 0.3 m								
Manning's roughness (n)	0.050	0.047	0.044	0.043	0.042	0.041	0.039	0.038	0.037
Drain slope (%)	3.3	4.2	5.1	5.6	6.1	7.2	8.3	9.5	11.3
	Type-CV catch drain: flow width (T) = 3.0 m and flow depth (Y) = 0.5 m								
Manning's roughness (n)	0.044	0.041	0.039	0.038	0.038	0.037	0.035	0.035	0.033
Drain slope (%)	1.3	1.7	2.1	2.3	2.5	2.9	3.4	3.9	4.7

[1] The allowable velocity for grass-lined channels can be determined from Table A28 of IECA (2008) Appendix A – *Construction site hydrology and hydraulics.* Typically, an allowable flow velocity of around 1.5 to 2.0m/s is used.

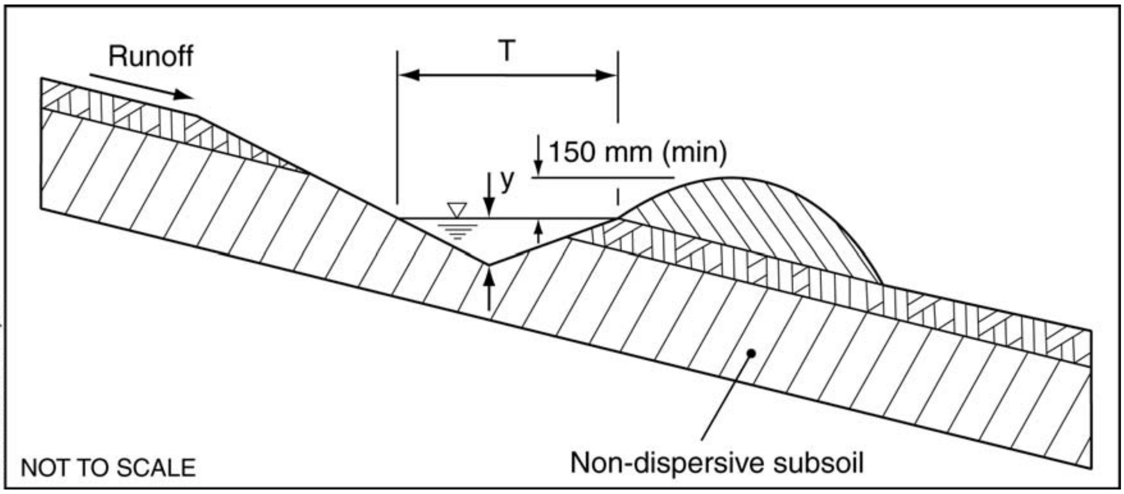

Figure 6(2) – Triangular V-drain with down-slope bank

Table 25 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-AV Catch Drain: V-drain cross section

Dimensions:				Flow top width = 1.0 m				Flow depth = 0.15 m		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	**3.0**
15	1.800	2.160	2.520	2.700	2.880	3.240	3.600	3.960	4.500	5.400
20	1.350	1.620	1.890	2.025	2.160	2.430	2.700	2.970	3.375	4.050
25	1.080	1.296	1.512	1.620	1.728	1.944	2.160	2.376	2.700	3.240
30	0.900	1.080	1.260	1.350	1.440	1.620	1.800	1.980	2.250	2.700
35	0.771	0.926	1.080	1.157	1.234	1.389	1.543	1.697	1.929	2.314
40	0.675	0.810	0.945	1.013	1.080	1.215	1.350	1.485	1.688	2.025
45	0.600	0.720	0.840	0.900	0.960	1.080	1.200	1.320	1.500	1.800
50	0.540	0.648	0.756	0.810	0.864	0.972	1.080	1.188	1.350	1.620
55	0.491	0.589	0.687	0.736	0.785	0.884	0.982	1.080	1.227	1.473
60	0.450	0.540	0.630	0.675	0.720	0.810	0.900	0.990	1.125	1.350
65	0.415	0.498	0.582	0.623	0.665	0.748	0.831	0.914	1.038	1.246
70	0.386	0.463	0.540	0.579	0.617	0.694	0.771	0.849	0.964	1.157
75	0.360	0.432	0.504	0.540	0.576	0.648	0.720	0.792	0.900	1.080
80	0.338	0.405	0.473	0.506	0.540	0.608	0.675	0.743	0.844	1.013
85	0.318	0.381	0.445	0.476	0.508	0.572	0.635	0.699	0.794	0.953
90	0.300	0.360	0.420	0.450	0.480	0.540	0.600	0.660	0.750	0.900
95	0.284	0.341	0.398	0.426	0.455	0.512	0.568	0.625	0.711	0.853
100	0.270	0.324	0.378	0.405	0.432	0.486	0.540	0.594	0.675	0.810
105	0.257	0.309	0.360	0.386	0.411	0.463	0.514	0.566	0.643	0.771
110	0.245	0.295	0.344	0.368	0.393	0.442	0.491	0.540	0.614	0.736
115	0.235	0.282	0.329	0.352	0.376	0.423	0.470	0.517	0.587	0.704
120	0.225	0.270	0.315	0.338	0.360	0.405	0.450	0.495	0.563	0.675
125	0.216	0.259	0.302	0.324	0.346	0.389	0.432	0.475	0.540	0.648
130	0.208	0.249	0.291	0.312	0.332	0.374	0.415	0.457	0.519	0.623
135	0.200	0.240	0.280	0.300	0.320	0.360	0.400	0.440	0.500	0.600
140	0.193	0.231	0.270	0.289	0.309	0.347	0.386	0.424	0.482	0.579
145	0.186	0.223	0.261	0.279	0.298	0.335	0.372	0.410	0.466	0.559
150	0.180	0.216	0.252	0.270	0.288	0.324	0.360	0.396	0.450	0.540
155	0.174	0.209	0.244	0.261	0.279	0.314	0.348	0.383	0.435	0.523
160	0.169	0.203	0.236	0.253	0.270	0.304	0.338	0.371	0.422	0.506
165	0.164	0.196	0.229	0.245	0.262	0.295	0.327	0.360	0.409	0.491
170	0.159	0.191	0.222	0.238	0.254	0.286	0.318	0.349	0.397	0.476
175	0.154	0.185	0.216	0.231	0.247	0.278	0.309	0.339	0.386	0.463
180	0.150	0.180	0.210	0.225	0.240	0.270	0.300	0.330	0.375	0.450
185	0.146	0.175	0.204	0.219	0.234	0.263	0.292	0.321	0.365	0.438
190	0.142	0.171	0.199	0.213	0.227	0.256	0.284	0.313	0.355	0.426
200	0.135	0.162	0.189	0.203	0.216	0.243	0.270	0.297	0.338	0.405
210	0.129	0.154	0.180	0.193	0.206	0.231	0.257	0.283	0.321	0.386
220	0.123	0.147	0.172	0.184	0.196	0.221	0.245	0.270	0.307	0.368
230	0.117	0.141	0.164	0.176	0.188	0.211	0.235	0.258	0.293	0.352
240	0.113	0.135	0.158	0.169	0.180	0.203	0.225	0.248	0.281	0.338
250	0.108	0.130	0.151	0.162	0.173	0.194	0.216	0.238	0.270	0.324
Q (m^3/s)	**0.075**	**0.090**	**0.105**	**0.113**	**0.120**	**0.135**	**0.150**	**0.165**	**0.188**	**0.225**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 24).

Table 26 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-BV Catch Drain: V-drain cross section										
Dimensions:				Flow top width = 1.8 m				Flow depth = 0.3 m		
Rainfall intensity (mm/hr)	Allowable flow velocity along catch drain (m/s)									
	1.0	1.2	1.4	1.5	1.6	1.8	2.0	2.2	2.5	3.0
15	6.480	7.776	9.072	9.720	10.368	11.664	12.960	14.256	16.200	19.440
20	4.860	5.832	6.804	7.290	7.776	8.748	9.720	10.692	12.150	14.580
25	3.888	4.666	5.443	5.832	6.221	6.998	7.776	8.554	9.720	11.664
30	3.240	3.888	4.536	4.860	5.184	5.832	6.480	7.128	8.100	9.720
35	2.777	3.333	3.888	4.166	4.443	4.999	5.554	6.110	6.943	8.331
40	2.430	2.916	3.402	3.645	3.888	4.374	4.860	5.346	6.075	7.290
45	2.160	2.592	3.024	3.240	3.456	3.888	4.320	4.752	5.400	6.480
50	1.944	2.333	2.722	2.916	3.110	3.499	3.888	4.277	4.860	5.832
55	1.767	2.121	2.474	2.651	2.828	3.181	3.535	3.888	4.418	5.302
60	1.620	1.944	2.268	2.430	2.592	2.916	3.240	3.564	4.050	4.860
65	1.495	1.794	2.094	2.243	2.393	2.692	2.991	3.290	3.738	4.486
70	1.389	1.666	1.944	2.083	2.222	2.499	2.777	3.055	3.471	4.166
75	1.296	1.555	1.814	1.944	2.074	2.333	2.592	2.851	3.240	3.888
80	1.215	1.458	1.701	1.823	1.944	2.187	2.430	2.673	3.038	3.645
85	1.144	1.372	1.601	1.715	1.830	2.058	2.287	2.516	2.859	3.431
90	1.080	1.296	1.512	1.620	1.728	1.944	2.160	2.376	2.700	3.240
95	1.023	1.228	1.432	1.535	1.637	1.842	2.046	2.251	2.558	3.069
100	0.972	1.166	1.361	1.458	1.555	1.750	1.944	2.138	2.430	2.916
105	0.926	1.111	1.296	1.389	1.481	1.666	1.851	2.037	2.314	2.777
110	0.884	1.060	1.237	1.325	1.414	1.591	1.767	1.944	2.209	2.651
115	0.845	1.014	1.183	1.268	1.352	1.521	1.690	1.859	2.113	2.536
120	0.810	0.972	1.134	1.215	1.296	1.458	1.620	1.782	2.025	2.430
125	0.778	0.933	1.089	1.166	1.244	1.400	1.555	1.711	1.944	2.333
130	0.748	0.897	1.047	1.122	1.196	1.346	1.495	1.645	1.869	2.243
135	0.720	0.864	1.008	1.080	1.152	1.296	1.440	1.584	1.800	2.160
140	0.694	0.833	0.972	1.041	1.111	1.250	1.389	1.527	1.736	2.083
145	0.670	0.804	0.938	1.006	1.073	1.207	1.341	1.475	1.676	2.011
150	0.648	0.778	0.907	0.972	1.037	1.166	1.296	1.426	1.620	1.944
155	0.627	0.753	0.878	0.941	1.003	1.129	1.254	1.380	1.568	1.881
160	0.608	0.729	0.851	0.911	0.972	1.094	1.215	1.337	1.519	1.823
165	0.589	0.707	0.825	0.884	0.943	1.060	1.178	1.296	1.473	1.767
170	0.572	0.686	0.800	0.858	0.915	1.029	1.144	1.258	1.429	1.715
175	0.555	0.667	0.778	0.833	0.889	1.000	1.111	1.222	1.389	1.666
180	0.540	0.648	0.756	0.810	0.864	0.972	1.080	1.188	1.350	1.620
185	0.525	0.630	0.736	0.788	0.841	0.946	1.051	1.156	1.314	1.576
190	0.512	0.614	0.716	0.767	0.819	0.921	1.023	1.125	1.279	1.535
200	0.486	0.583	0.680	0.729	0.778	0.875	0.972	1.069	1.215	1.458
210	0.463	0.555	0.648	0.694	0.741	0.833	0.926	1.018	1.157	1.389
220	0.442	0.530	0.619	0.663	0.707	0.795	0.884	0.972	1.105	1.325
230	0.423	0.507	0.592	0.634	0.676	0.761	0.845	0.930	1.057	1.268
240	0.405	0.486	0.567	0.608	0.648	0.729	0.810	0.891	1.013	1.215
250	0.389	0.467	0.544	0.583	0.622	0.700	0.778	0.855	0.972	1.166
Q (m^3/s)	0.270	0.324	0.378	0.405	0.432	0.486	0.540	0.594	0.675	0.810

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 24).

Table 27 – Maximum allowable unit catchment area (A*, hectares) [1]

Type-CV Catch Drain: V-drain cross section

Dimensions:				Flow top width = 3.0 m				Flow depth = 0.5 m		
Rainfall intensity (mm/hr)	**Allowable flow velocity along catch drain (m/s)**									
	1.0	**1.2**	**1.4**	**1.5**	**1.6**	**1.8**	**2.0**	**2.2**	**2.5**	**3.0**
15	18.00	21.60	25.20	27.00	28.80	32.40	36.00	39.60	45.00	54.00
20	13.50	16.20	18.90	20.25	21.60	24.30	27.00	29.70	33.75	40.50
25	10.80	12.96	15.12	16.20	17.28	19.44	21.60	23.76	27.00	32.40
30	9.00	10.80	12.60	13.50	14.40	16.20	18.00	19.80	22.50	27.00
35	7.71	9.26	10.80	11.57	12.34	13.89	15.43	16.97	19.29	23.14
40	6.75	8.10	9.45	10.13	10.80	12.15	13.50	14.85	16.88	20.25
45	6.00	7.20	8.40	9.00	9.60	10.80	12.00	13.20	15.00	18.00
50	5.40	6.48	7.56	8.10	8.64	9.72	10.80	11.88	13.50	16.20
55	4.91	5.89	6.87	7.36	7.85	8.84	9.82	10.80	12.27	14.73
60	4.50	5.40	6.30	6.75	7.20	8.10	9.00	9.90	11.25	13.50
65	4.15	4.98	5.82	6.23	6.65	7.48	8.31	9.14	10.38	12.46
70	3.86	4.63	5.40	5.79	6.17	6.94	7.71	8.49	9.64	11.57
75	3.60	4.32	5.04	5.40	5.76	6.48	7.20	7.92	9.00	10.80
80	3.38	4.05	4.73	5.06	5.40	6.08	6.75	7.43	8.44	10.13
85	3.18	3.81	4.45	4.76	5.08	5.72	6.35	6.99	7.94	9.53
90	3.00	3.60	4.20	4.50	4.80	5.40	6.00	6.60	7.50	9.00
95	2.84	3.41	3.98	4.26	4.55	5.12	5.68	6.25	7.11	8.53
100	2.70	3.24	3.78	4.05	4.32	4.86	5.40	5.94	6.75	8.10
105	2.57	3.09	3.60	3.86	4.11	4.63	5.14	5.66	6.43	7.71
110	2.45	2.95	3.44	3.68	3.93	4.42	4.91	5.40	6.14	7.36
115	2.35	2.82	3.29	3.52	3.76	4.23	4.70	5.17	5.87	7.04
120	2.25	2.70	3.15	3.38	3.60	4.05	4.50	4.95	5.63	6.75
125	2.16	2.59	3.02	3.24	3.46	3.89	4.32	4.75	5.40	6.48
130	2.08	2.49	2.91	3.12	3.32	3.74	4.15	4.57	5.19	6.23
135	2.00	2.40	2.80	3.00	3.20	3.60	4.00	4.40	5.00	6.00
140	1.93	2.31	2.70	2.89	3.09	3.47	3.86	4.24	4.82	5.79
145	1.86	2.23	2.61	2.79	2.98	3.35	3.72	4.10	4.66	5.59
150	1.80	2.16	2.52	2.70	2.88	3.24	3.60	3.96	4.50	5.40
155	1.74	2.09	2.44	2.61	2.79	3.14	3.48	3.83	4.35	5.23
160	1.69	2.03	2.36	2.53	2.70	3.04	3.38	3.71	4.22	5.06
165	1.64	1.96	2.29	2.45	2.62	2.95	3.27	3.60	4.09	4.91
170	1.59	1.91	2.22	2.38	2.54	2.86	3.18	3.49	3.97	4.76
175	1.54	1.85	2.16	2.31	2.47	2.78	3.09	3.39	3.86	4.63
180	1.50	1.80	2.10	2.25	2.40	2.70	3.00	3.30	3.75	4.50
185	1.46	1.75	2.04	2.19	2.34	2.63	2.92	3.21	3.65	4.38
190	1.42	1.71	1.99	2.13	2.27	2.56	2.84	3.13	3.55	4.26
200	1.35	1.62	1.89	2.03	2.16	2.43	2.70	2.97	3.38	4.05
210	1.29	1.54	1.80	1.93	2.06	2.31	2.57	2.83	3.21	3.86
220	1.23	1.47	1.72	1.84	1.96	2.21	2.45	2.70	3.07	3.68
230	1.17	1.41	1.64	1.76	1.88	2.11	2.35	2.58	2.93	3.52
240	1.13	1.35	1.58	1.69	1.80	2.03	2.25	2.48	2.81	3.38
250	1.08	1.30	1.51	1.62	1.73	1.94	2.16	2.38	2.70	3.24
Q (m^3/s)	**0.750**	**0.900**	**1.050**	**1.125**	**1.200**	**1.350**	**1.500**	**1.650**	**1.875**	**2.250**

[1] Catchment areas are based on the drain being formed at the required longitudinal gradient (Table 24).