Flow Diversion Banks: On grassed slopes

DRAINAGE CONTROL TECHNIQUE

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

[1] Flow diversion banks are not commonly used as permanent drainage structures.

Symbol → DB →

Photo 10 – Turf-lined flow diversion bank with grass-lined outlet chutes at regular intervals along the embankment

Photo 11 – Flow diversion bank up-slope of a building site – the bank also acts as a [illegible] topsoil stockpile

Key Principles

1. Key design parameters are the effective flow capacity of the structure, and the scour resistance of the embankment material.
2. The critical operational issue is usually preventing structural damage to the embankment as a result of high velocity flows or construction traffic.
3. Flow diversion banks are often favoured over *Catch Drains* in areas containing dispersive subsoil because their construction does not require exposure of the subsoils.

Design Information

The material contained within this fact sheet has been supplied for use by persons experienced in hydraulic design.

Recommended allowable flow velocities for open earth surfaces are provided in Tables 19 & 20. The maximum flow velocity (i.e. the velocity most likely to cause erosion of the earth surface) is most likely to occur at the toe of the embankment where flow depth (y) is a maximum. In wide, shallow drains, such as typically occur adjacent flow diversion banks, the local flow velocity is dependent on the local flow depth rather than the hydraulic radius (R).

Table 21 presented the expected maximum flow velocity for various maximum flow depths and longitudinal channel gradients.

Tables 22 to 29 provide the expected flow capacity for flow diversion bank operating a various maximum flow depths on an open earth surface. These tables are based on an embankment side slope of 2:1 (H:V), and a Manning's roughness determined from Equation 1, but limited to a maximum value of, n = 0.2 and a minimum value of, n = 0.03.

Note; flow capacity is presented in units of [L/s] in Tables 22 to 25, and units of [m^3/s] in Tables 26 to 29.

Table 19 – Allowable flow velocity (m/s) for grass-lined drains [1]

Percentage grass cover	Gradient (S) along drain (%)									
	1	2	3	4	5	6	8	10	15	20
70% [2]										
100% [3]										
Poor soils [4]										

[1] Maximum allowable flow velocity limited to .....m/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 ....

[3] 100% cover is typical for ....

[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 20 – Manning's roughness for grassed surfaces (50–150mm blade) [1]

R (m)	Gradient (S) along drain (%)					
	1	2	3	4	5	10
0.10						
0.15						
0.20						
0.25						
0.30						
0.40						
0.50						

[1] Manning's n values may be approximated by Equation 2 (units of R [m] and S [m/m]). Note, minimum recommended Manning's roughness, n = 0.030. Caution use of Equation 2 for low values of hydraulic radius (negative values can occur).

Class D roughness: (Eqn 2)

Table 21 – Maximum flow velocity (toe of embankment) on earth surface (m/s) [1]

Flow depth	Gradient (S) along drain (%)									
	0.5	1	2	3	4	5	6	8	10	15
0.05										
0.10										
0.15										
0.20										
0.25										
0.30										
0.35										
0.50										

[1] Maximum flow velocity refers to the maximum local flow velocity, which would ....The velocity has been determined using Manning's equation based on a hydraulic radius (R) equal to the local flow depth (y), and Manning's roughness determined from Equation 2, but limited to a maximum value of, n = 0.2 and a minimum value of, n = 0.03.

Hydraulic design of flow diversion banks:

Step 1 Determine the required design discharge based on the effective catchment area of the flow diversion bank.

Step 2 Determine the cross-sectional profile and surface condition. This fact sheet assumes the flow surface primarily consists of a grassed (50-150mm) surface.

Step 3 ....

Step 4 If the longitudinal gradient (S) of the drainage channel formed by the bank is known (i.e. set by site conditions), then determine the maximum allowable flow depth (y) from Table 21 given the allowable flow velocity determined in Step 3.

The maximum allowable flow depth (y) can also be determined directly from:

$$y = \frac{(n.V)^{3/2}}{S^{3/4}} \qquad \text{(S has units of m/m)}$$

If the longitudinal gradient of the drainage channel is not set by site conditions, then nominate a gradient from Table 21 based on a desirable maximum flow depth.

The maximum allowable longitudinal drainage gradient (S) can also be determined directly from:

$$S = \frac{(n.V)^2}{y^{4/3}} \qquad \text{(S has units of m/m)}$$

Step 5 Determine the ....

Step 6 Determine the cross-sectional flow area (A) and hydraulic radius (R).

Step 7 Determine the maximum allowable flow capacity (Q) of the flow diversion bank based on the values of n, A, R and S determined above.

Manning equation: $Q = (1/n)\, A\, R^{2/3}\, S^{1/2}$

Tables 22 to 29 provide flow capacities based on a simple triangular cross-sectional profile, an embankment side slope of 2:1 (H:V), and a Manning's roughness for a grassed surface determined from Equation 2, but limited to a maximum value of, n = 0.2 and a minimum value of, n = 0.03.

If the maximum flow capacity is less than the design discharge determined in Step 1, then it will be necessary to reduce the effective catchment area and design discharge of the flow diversion bank.

Alternatively, the scour resistance of the surface condition could be improved through appropriate erosion control measures, or the longitudinal gradient (S) of the drainage channel. Determine the required gradient (S) using Manning's equation.

$$S = \frac{(n.V)^2}{y^{4/3}} \qquad \text{(S has units of m/m)}$$

Step 8 Determined the required freeboard given the embankment type – refer to Table 1 in fact sheet: *Flow Diversion Banks – General*.

Step 9 ....

Step 10 Specify the overall dimensions of the flow diversion bank, including freeboard.

Step 11 Ensure the drainage embankment discharges to an appropriate, stable outlet.

Step 12 Appropriately consider all likely safety issues, and modify the embankment and/or surrounding environment where required.

Design example:

Design a vegetated (grassed) flow diversion bank capable of carrying a design discharge of $1.5m^3/s$ across a slope with a gradient of 3% (33:1) (note; this is the gradient of the land slope, <u>not</u> the drain slope).

Step 1 The required design discharge is $1.5m^3/s$.

Step 2 Assume a simple triangular cross-sectional profile with fully exposed earth surface.

Step 3 ....

Step 4 A vegetated embankment is assumed, thus the recommended minimum freeboard is 150mm. This means for an embankment height of 500mm, the maximum flow depth (y) is 500 - 150 = 350mm. If is flow depth is insufficient, then an embankment height greater than 500mm may be considered.

Given y = 350mm, and V_{allow} = 2.0m/s, choose a longitudinal gradient (S) of 2% from Table 19.

Step 5 ....

Step 6 There is no need to determine the cross-sectional flow area (A) and hydraulic radius (R) because the supplied design tables will be used. However, for demonstration purposes, given a maximum flow depth, y = 0.35m; embankment side slope, a = 2; and land slope, b = 33 (i.e. 3%); then:

$$A = 2.164m^2$$

$$R = 0.17[illegible]$$

[illegible] = 0.0[illegible]

Step 7 Given a maximum flow depth, y = 0.35m; land slope, b = 3%; and longitudinal drain slope, S = 2%; from Table [illegible] the maximum flow capacity (Q) is:

$$Q_{max} = 1.917m^3/s > 1.5m^3/s \quad OK$$

Thus the flow diversion bank will have adequate flow capacity to carry the design discharge of $1.5m^3/s$.

Step 8 From Table 1 the required minimum freeboard for a vegetated earth embankment is 150mm.

Step 9 ....

Step 10 Specify the overall dimensions of the flow diversion bank, including freeboard.

Embankment height of 00mm

Embankment side slopes of ....:1 (H:V)

Base width of embankment of 2500mm

Freeboard of 150mm

Longitudinal gradient of embankment of ....%

Step 11 Ensure the drainage embankment discharges to an appropriate, stable outlet.

Step 12 Appropriately consider all likely safety issues, and modify the embankment and/or surrounding environment where required.

Note, the allowable flow depth (y) is limited by the drain gradient and the allowable flow velocity.

Table 22 – Flow capacity (L/s) for flow diversion banks on grassed surface [1]

Flow diversion bank on grassed surface					Flow depth, y = 0.10m					
Land slope %	Gradient (S) along drain (%)									
	0.10	0.50	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

[1] NOTE: Flow rate is presented in units of litres per second, not m^3/s as used in Tables 26 to 29.

Table 23 – Flow capacity (L/s) for flow diversion banks on grassed surface [1]

Flow diversion bank on grassed surface					Flow depth, y = 0.15m					
Land slope %	Gradient (S) along drain (%)									
	0.10	0.50	1.0	2.0	3.0	4.0	5.0	6.0	8.0	10.0
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

[1] NOTE: Flow rate is presented in units of litres per second, <u>not</u> m^3/s as used in Tables 26 to 29.

Note, the allowable flow depth (y) is limited by the drain gradient and the allowable flow velocity.

Table 24 – Flow capacity (L/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface						Flow depth, y = 0.20m				
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

[1] NOTE: Flow rate is presented in units of litres per second, not m^3/s as used in Tables 26 to 29.

Table 25 – Flow capacity (L/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface						Flow depth, y = 0.25m				
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

[1] NOTE: Flow rate is presented in units of litres per second, <u>not</u> m^3/s as used in Tables 26 to 29.

Note, the allowable flow depth (y) is limited by the drain gradient and the allowable flow velocity.

Table 26 – Flow capacity (m^3/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface					Flow depth, y = 0.30m					
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

Table 27 – Flow capacity (m^3/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface					Flow depth, y = 0.35m					
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

Note, the allowable flow depth (y) is limited by the drain gradient and the allowable flow velocity.

Table 28 – Flow capacity (m^3/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface						Flow depth, y = 0.40m				
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										

Table 29 – Flow capacity (m^3/s) for flow diversion banks on grassed surface

Flow diversion bank on grassed surface						Flow depth, y = 0.50m				
Land slope %	Gradient (S) along drain (%)									
	0.1	0.5	1	2	3	4	5	6	8	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
12										
15										
20										
25										
33.3										
50										