VOLUME 4 GEOTECHNICS AND DRAINAGE
SECTION 2 DRAINAGE

PART 3

HA 102/00

SPACING OF ROAD GULLIES

SUMMARY

This Advice Note provides design guidance for determining the length of road between gullies that can be drained by grating and kerb outlets to BS EN 124 and BS 7903. It contains methods using either tables or a full calculation procedure. It updates and replaces TRRL Contractor Report 2.

INSTRUCTIONS FOR USE

This is a new document to be incorporated into the Manual.

1. Insert HA 102/00 into Volume 4, Section 2.

2. Archive this sheet as appropriate.

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THE SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

THE NATIONAL ASSEMBLY FOR WALES
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THE DEPARTMENT FOR REGIONAL DEVELOPMENT*

Spacing of Road Gullies

* A Government Department in Northern Ireland

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Contents

Chapter

Annexes

1. INTRODUCTION

General

1.1 This Advice Note describes a design method for determining the spacing of road gratings and kerb inlets for removing surface water from trunk roads (including motorways) with an acceptable width of channel flow. It replaces the design method provided by TRL Contractor Report 2 [Ref 3] referred to in HD 33 (DMRB 4.2.3). Contractor Report 2 should no longer be used. The research on which this method is based is described in Ref 4.

1.2 Road gullies are now specified by BS EN 124 [Ref 6] and the accompanying BS 7903 [Ref 7]. The EN allows a wider range of grating geometries than the superseded BS 497 [Ref 8] which was withdrawn in 1994.

1.3 It is assumed that the limiting factor in determining spacing between gullies is the flow capacity of the grating and not that of the associated gully pot or associated pipework. Guidance on the flow capacity of gully pots is given in Section 5.24 of this document.

1.4 "Kerbs and gullies" is a widely used form of surface drainage. HD 33 gives guidance on the use of these types of drainage in motorways and trunk roads.

1.5 It is recommended in HD 33 and TD9 (DMRB 6.1.1) that particular attention should be paid to longitudinal gradients on superelevations, with a minimum of 1/200 (0.5%). Careful consideration should also be given to road profiling and gradients on roundabouts.

Scope

1.6 The hydraulic design of road gratings and kerb inlets should take account of two factors:

(i) The flow of water parallel to the kerb should not exceed an allowable width (B in Figures 1a and 1b). An excessive width can be an inconvenience or danger to traffic. When checked for 1 in 5 year storm the maximum flow width is 1.5m for the hard shoulder and 1.0m for the hard strip on trunk roads. For non-trunk roads guidance is given in HA83 (DMRB 4.2.4).

(ii) The grating of the gully or kerb inlet should be reasonably efficient in collecting the flow. That is, the percentage η of the approaching flow that enters the grating should be as high as possible (Figure 1b). Any water not collected flows past the grating, augmenting the flow in the next downstream section.

1.7 The design method given in this Note has been tested over the range of longitudinal gradients between 1/300 (0.33%) and 1/15 (6.67%) shown in the tables in Annex C. It can reasonably be extended to a gradient of 1/12.5 (8.00%).

1.8 Flat longitudinal gradients may be unavoidable in some situations. Road gullies do have an advantage over surface water channels since the gradient to carry the road runoff from the gully to the outfall is not dependent on the gradient of the road. They do not however usually provide the best drainage solution for long lengths of flat gradients. The procedure for the drainage of level or nearly level roads is given in TRL LR 602 [Ref 9].

1.9 For steep longitudinal gradients and wide flows, gratings and kerb inlets become inefficient because too much water bypasses the grating. The design method in this Advice Note informs the Designer or Specifier when this will happen.

1.10 Gratings for use as outlets to surface water channels are dealt with in HA 78 (DMRB 4.2.1).

1.11 The design of kerbs is dealt with in TA 57 (DMRB 6.3) and in BS 7263 [Ref 12].

Safety

1.12 Safety aspects of edge details are generally functions of the location, form and size of edge restraint detail, and any associated safety barrier or safety fence provision. Roadside drainage features are primarily designed to remove surface water. Since they are placed along the side of the carriageway, they should not normally pose any physical hazard to road users. It is only in the rare event of a vehicle becoming errant that the consequential effects of a roadside drainage feature upon a vehicle become apparent. Whilst the behaviour of an errant vehicle and its occupants is unpredictable and deemed to be hazardous, the designer must consider carefully the safety of the design and minimise potential hazards as far as possible (HD 33; DMRB 4.2.3). However, regard should be had to the particular requirements of vulnerable road users.

1.13 BS EN 124 allows grating slots parallel to the kerb which may present a serious hazard to cyclists. If there is a possibility of cyclists crossing a grating, the slots should not be at an angle likely to affect their passage (TA 57; DMRB 6.3). It is common UK practice that slots are aligned at between 45º and 90º to the kerb.

Implementation

1.14 This Advice Note should be used forthwith for all schemes currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation. The requirements for gully gratings are given in Clause 508 of the Specification for Highway Works (MCHW 1), the corresponding Notes for Guidance (MCHW 2), and Drawing No F9 of the Highway Construction Details (MCHW 3). It is not intended that gully spacings on existing roads should be recalculated unless there are drainage problems which need to be addressed.

2. TYPES OF GULLY GRATING

Structural characteristics

2.1 The required strength class for gully gratings should normally be obtained from BS EN 124. For trunk roads a minimum strength class will normally be D400. Where heavier duty gratings are required, eg motorway running lanes, advice should be sought from the Overseeing Organisation.

Hydraulic characteristics

2.2 The hydraulic capacity of a gully grating depends on its overall size, the number and orientation of the slots, and the total waterway area provided by the slots. BS EN 124 places limitations on the minimum and maximum dimensions of slots based on considerations of safety and potential blockage by silt and debris. In order to ensure a reasonable level of hydraulic performance, the Standard also specifies that the total waterway area of the slots should not be less than 30% of the clear area (see Section 7).

2.3 BS 7903 also recommends that the portion of the total waterway area within 50mm of the kerb should not be less than 45 cm^2. Gullies will normally be rectangular or triangular with one side adjacent to the kerb. Circular gullies, and any other shapes that are highly asymmetric in a direction transverse to the kerb, are unlikely to be acceptable. The kerb face of the frame should be hard against the kerb.

2.4 The hydraulic design method in this Advice Note assumes that the gap between the kerb and the first slot(s) of a gully grating is not greater than 50mm.

2.5 In order to deal with the large number of possible designs that could be produced, this Advice Note sets out a method of classifying gratings based on their hydraulic characteristics - Types P, Q, R, S or T in decreasing hydraulic capacity. The advantage of this approach is that the Designer or Specifier is able to specify a grating type and be sure of achieving the required hydraulic performance whatever make of conforming grating is chosen by the contractor.

2.6 Classification will normally be determined by the calculation in Annex B, based upon the geometric characteristics of the grating. It may be carried out by any of the following means:

(i) It is expected that manufacturers will carry out the calculations necessary to classify their product.

(ii) In the absence of manufacturer's calculations, the Designer or Specifier may need to carry out the calculations.

(iii) Should a manufacturer wish to carry out hydraulic tests to determine the classification of a grating, a suitable test procedure is described by Spaliviero et al [Ref 4].

2.7 A grating is only a small part of the total cost of a gully. If a given grating is not functioning effectively, it will usually be more economic to use a more efficient type of grating rather than decrease the spacing between gratings.

3. TYPES OF KERB INLET

Structural characteristics

3.1 For the purposes of this Advice Note, kerb inlets are defined as manufactured units that when installed along the line of a kerb provide a series of openings parallel to the flow and through each of which water can be discharged via a gully pot to the below-ground pipe system. Other types of kerb drainage system having continuous slots or closely-spaced holes that discharge into a longitudinal pipe or channel formed within the kerb unit are outside the scope of this Advice Note.

3.2 Requirements for the mechanical properties and strength of kerb inlets are given in BS EN 124.

Hydraulic characteristics

3.3 BS EN 124 does not set any limitations on the size and geometry of kerb inlets that affect their hydraulic capacity.

3.4 A kerb inlet usually has a considerably lower flow collection capacity than a gully grating of similar length. This is because the velocity of water along a kerb channel limits the proportion of the total flow that is able to turn into the opening provided by the kerb inlet.

3.5 A method of increasing the efficiency of a kerb inlet is to create a longer opening parallel to the flow by recessing the upstream kerb line and setting the kerb inlet at a greater angle to the flow (see Figure 2). To prevent flow separating from the recessed section of kerb, the angle β in Figure 2 should not be greater than about 14º, corresponding to an expansion angle of 1:4. For reasons of vehicle safety, angled kerb inlets of this type should only be used where the direction of water flow is opposite to that of the traffic in the carriageway adjacent to the kerb. Also angled kerb inlets can become blocked with debris and can be difficult to sweep.

4. FACTORS AFFECTING HYDRAULIC DESIGN

4.1 The Designer or Specifier will need to evaluate the hydraulic parameters set out in this chapter before commencing the design procedure.

4.2 The Designer or Specifier should make an initial assumption about the most suitable grating type (P to T) for a particular scheme, and upgrade this if it does not prove satisfactory.

4.3 The Manning roughness coefficient of the channel (n) should normally be taken as 0.017 for a blacktop surface. Some other values are given in Table 1 from HA 37 (DMRB 4.2.4).

Table 1 Values of Manning's n

Surface	Condition	n
Concrete	Average	0.013
Concrete	Poor	0.016
Blacktop	Average	0.017
Blacktop	Poor	0.021

4.4 Design storm return periods, and permissible flow widths along the kerb, are given in HD 33 (DMRB 4.2.3).

4.5 The efficiency of the gully may be reduced by the accumulation of debris not immediately cleared by maintenance operations. Factors to take account of this are given in Section 4.16 of this Advice Note.

4.6 The location of some gullies must first be fixed by the considerations given in Sections 4.7 to 4.10. The location and spacing for other gullies may then be determined by the design method given in this Advice Note. Calculations should commence at the crests or highest point of the scheme and proceed downhill. A distinction is made between two modes of hydraulic operation of gullies:

- **Intermediate gullies** are those for which some calculated proportion of the approaching flow may be permitted to continue past the gully, to be picked up by the next gully downstream (Figure 1b).

- **Terminal gullies** are those for which no significant proportion of the approaching flow may be permitted to pass the gully, either because there is no downstream gully or because the passing flow will interfere with traffic.

4.7 The designer should be aware of the future maintenance requirements at the gully location and ensure that this activity will not compromise access, safety of cyclists or restrict traffic flow.

4.8 A particular problem occurs at sag points in gradients, both because floating debris will tend to accumulate at this point, and because any water not entering a gully at this point cannot pass to another gully. A gully, or preferably twin gullies, should always be placed at this point, and a substantial reduction in efficiency be allowed for in the design method.

4.9 If the crest along a length of road with changing longitudinal gradient is well defined, no gully will be needed at this point. If, however, there is a slow transition from negative to positive gradient, a gully may need to be placed at the crest to deal with any significant length of flat gradient.

4.10 In cases such as the following it may be beneficial to install an additional upstream gully:

- transitions to superelevations

- a pedestrian or cycle crossing

- for steeply angled road junctions.

This gully should be designed to operate as a terminal gully. Where a pedestrian or cycle crossing occurs at the lowest point of the road, the crossing should be relocated.

4.11 The longitudinal gradient will probably be fixed by other considerations, but adjustment of the road geometry should be considered to avoid flat gradients and rollovers that cause problems with drainage. The geometric standards for the relevant scheme should be checked to determine the extent of any flexibility.

4.12 Subject to the geotechnical considerations outlined in HA 39 (DMRB 4.2.4), it may be possible to reduce local flooding by permitting overflow over the kerb onto a shallow embankment slope or grassed verge but ensuring that the footway is not flooded.

Rainfall

4.13 The design rainfall intensity I (mm/h) for a storm with a return period of N years may be determined from the formula given in HA 37 (DMRB 4.2.2):

$$I = 32.7(N - 0.4)^{0.223} (T - 0.4)^{0.565} (2minM5)/T \qquad (1)$$

The quantity 2minM5 is the rainfall depth in mm occurring at the site in a period of 2 minutes with an average return period of 5 years. This is a measure of the rainfall characteristics at the site and is reproduced in Figure 3. The critical storm duration T (in minutes) is the time of concentration of flow for the area served by the gully, and may normally be taken as 5 minutes*. Design values of the storm return period are given in HD 33 (DMRB 4.2.3).

4.14 It should be noted from Figure 3 of Annex D that the most severe rainfall conditions are to be expected in East Anglia and the South-East of England. Although these areas have much lower values of annual rainfall than parts of Wales, Scotland and the North-West of England, they experience heavier and more frequent short-duration storms, of the kind typically associated with summer thunderstorms.

Catchment width

4.15 The effective catchment width draining to the kerb channel, W_e (in m), may be determined from a plan area of the site. All paved areas draining to the kerb should be included, eg hard shoulders, paved central reserves, footways and even buildings where roof drainage discharges to the road gullies. It is difficult to estimate the contribution for unpaved areas, but provided the unpaved area does not exceed the paved area, it may normally be assumed that the contribution of unpaved areas is about 20% of that for an equivalent paved area. (A fuller discussion is given in HA 37; DMRB 4.2.4). Reference may be made to HA 37 for information on catchment areas and times of concentration.

* As a general guide, T may be significantly less than 5 minutes for gully spacings less than 10m with moderate to severe gradients. T may be significantly greater than 5 minutes for gully spacings greater than 50m with slacker gradients. A method of checking the value of T is given in Section 5.23.

Effect of maintenance

4.16 The effect of reduced maintenance and accumulation of debris will be to reduce the hydraulic area and efficiency of the grating. A maintenance factor 'm' is therefore included to allow for this effect. This has a value of 1.0 for no effect, and decreasing values for decreasing standards of maintenance. Factors should be based on site specific considerations. Suggested values for m are given in Table 2.

Table 2 Values of maintenance factor

Situation	Maintenance factor (m)
Well-maintained urban roads**	1.0
Roads subject to less frequent maintenance	0.9
Roads subject to substantial leaf falls or vehicle spillages (eg at sharp roundabouts)	0.8
Sag points on road gradients	0.7

** eg refer to TRMM[Ref 5]

5. DESIGN PROCEDURE

Hydraulic parameters required

5.1 The following parameters should be determined initially from the considerations outlined in Chapter 4:

- Values of the longitudinal gradient, $S_{L,}$ at points along the length of the scheme (expressed as fractions in the design tables and calculations). For an individual length drained by a gully, S_L should be taken as the average gradient over a 3m distance upstream of the gully.
- The cross-fall, S_c, also expressed as a fraction in the tables and calculations. It is measured 0.5m upstream of the leading edge of the gully and for the maximum permissible width of flow.
- The Manning roughness coefficient, n.
- The maximum allowable flow width against the kerb (B in m, Figure 1) given in HD 33 (DMRB 4.2.3).
- The grating type (P, Q, R, S or T), or the size and angle of kerb inlet.

Use of tables for determining flow capacity of gullies

5.2 A series of design tables is given in Annex C of this Advice Note. These may be used, subject to the limitations indicated, to determine gully spacings with the minimum of calculation. The equations on which they are based are given in later sections of this Advice Note. Sections 5.3 to 5.10 give the procedure for using the tables. Alternatively the equations given in Section 5.12 to 5.20 may be used directly. It should be noted that the tables refer to spacing of intermediate gullies. The procedure for terminal gullies is given in Section 5.21.

5.3 Table C1 in Annex C may be used to determine the discharge at the kerb immediately upstream of the grating if required. For intermediate values of cross-fall and gradient, the flow may be either interpolated or taken as the nearest higher value. For values of n other than 0.017, the flow should be multiplied by 0.017/n.

Maximum spacings for gully gratings

5.4 Tables C2 to C6 in Annex C give the area of road that may be drained (A_{dr} in m^2) by an intermediate gully for a rainfall intensity of 50mm/h, m = 1.0, and n = 0.017. Each of tables C2 to C6 corresponds to one of grating types P to T. The actual area (A_a) that can be drained is then given by:

$$A_a = A_{dr}\ (50/I)\ m\ k_n \qquad (2)$$

It is sufficiently accurate, where the grating efficiency η at n = 0.017 is more than about 80%, to set k_n to 0.017/n. The exact solution is:

$$k_n = \frac{(0.017\ /\ n) - \left(1 - \eta/100\right)(0.017\ /\ n)^2}{\eta\ /100} \qquad (3)$$

5.5 The maximum design spacing between adjacent intermediate gratings (S_p in m) is then given by:

$$S_p = A_a/W_e \qquad (4)$$

where W_e is the effective catchment area.

These tables also give the flow collection efficiency η of the grating in % (in brackets). If η is below about 60%, the grating is not very efficient, and the design should be reconsidered (see Section 5.25). The design method is intended to be applied over a range of η between 100 and 50%. Below 50%, it becomes increasingly conservative.

5.6 Tables C2 to C6 are for intermediate gullies on a uniform gradient, and are not strictly accurate for gradients which vary greatly over short distances. As a general guide, errors become significant if the gradients between adjacent gullies change by more than two of the increments in the tables, and also if the grating efficiency η is less than 80%. A more accurate calculation for this case is given in Section 5.16.

Maximum spacings for kerb inlets

5.7 Values of the catchment area (A_{dr} in m^2) that can be drained by 0.5m long and 1.5m long inlets installed in the line of the kerb are given in tables C7 and C8 respectively. Table C9 applies to the case of a 0.5m long inlet installed at angles α=50º and β=14º as shown in Figure 2 of Annex D; this arrangement is equivalent in performance to an in-line inlet providing a 1.85m long opening in the kerb. The values of A_{dr} given in the tables assume a rainfall intensity of I = 50 mm/h, a maintenance factor of m = 1.0 and a channel roughness of n = 0.017. If other values of I or m apply, the actual area, A_a , that can be drained will be different from A_{dr} and may be calculated from Equation (2). If tables C7 to C9 show that the flow collection efficiency, η, would be less than 60%, the use of either a longer kerb inlet or a suitable gully grating is recommended. For a given length, a gully grating will usually be more efficient than a kerb inlet.

5.8 The maximum allowable spacing between intermediate kerb inlets, S_p (in m), is calculated from Equation (4) using the value of A_a (in m^2) and the effective catchment width, W_e (in m).

5.9 The effect on the allowable drained area and spacing of assuming a different value of channel roughness, n, may be estimated approximately by setting k_n in Equation (2) to 0.017/n, provided the flow collection efficiency given for n = 0.017 in the appropriate tables C7 to C9 exceeds η = 80%. If the efficiency is lower the more accurate formula given in Equation (3) should be used.

5.10 The drained areas and spacings for other lengths of kerb inlet may be determined by applying an appropriate factor k_L to the values obtained from tables C7 to C9. Firstly the table for which the inlet length, L_{i1} (in m), is closest to the required length, L_{i2} (in m) should be chosen. From the table, the flow collection efficiency, η, corresponding to the length L_{i1} should be found, and the value of the factor k_L calculated from the formula:

$$k_L = \frac{1.0 - \left(1.0 - \dfrac{\eta}{100}\right)\left(\dfrac{L_{i1}}{L_{i2}}\right)}{\left(\dfrac{\eta}{100}\right)} \qquad (5)$$

The actual drained area (A_a) and the maximum spacing distance (S_p) corresponding to the inlet length L_{i1} should then be multiplied by the factor k_L to find the corresponding values for the required inlet length L_{i2}.

Use of equations for determining the flow capacity of gullies

5.11 If the design tables are being used without further calculation the following sections 5.12 to 5.20 may be passed over.

This section describes the equations used in the design procedure described in this Advice Note. They were used in compiling the design tables in Annex C, and may also be used for direct calculation of gully spacings. These equations may readily be programmed, and in this form are very easy to use for exploring the effects of changing the drainage parameters.

Flow capacity of kerb channel

5.12 The water depth against the kerb (H, in m) is given by:

$$H = BS_c \qquad (6)$$

The cross-sectional area of flow, A_f (in m^2), just upstream of the grating is given by:

$$A_f = BH/2 \qquad (7)$$

The hydraulic radius of the channel, R (in m), is given by:

$$R = \frac{A_f}{H + \sqrt{B^2 + H^2}} \qquad (8)$$

5.13 The flow rate, Q (in m^3/s) approaching the grating is calculated from Manning's equation:

$$Q = (A_f R^{2/3} S_L^{1/2}) / n \qquad (9)$$

Flow collection efficiency of gully grating

5.14 The flow collection efficiency, η (in %) is given by:

$$\eta = 100 - G_d (Q / H) \qquad (10)$$

G_d is the grating parameter and its value is determined by the grating type - see Annex B.

The acceptable range of values for η is discussed in Section 5.5.

Maximum design spacing of gully gratings

5.15 For intermediate gratings along a uniform longitudinal gradient, the maximum allowable spacing between adjacent gratings (S_p) may be calculated from the equation:

$$S_p = \left(3.6 \times 10^6 \, Q \, \frac{m\eta}{100}\right) \Big/ W_e \, I \tag{11}$$

5.16 For non-uniform gradients, the grating spacings are calculated going downstream for each pair of gratings, and Equation (11) is replaced by:

$$S_p = [3.6 \times 10^6 \{Q - Q_{us} (1 - m_{us}\eta_{us}/100)\}] / W_e I \tag{12}$$

where Q_{us}, m_{us} and η_{us} refer to the upstream grating. Calculations using this equation should commence at the upstream end. If the upstream end is at the top of a crest with no gully, Q_{us} becomes zero.

Flow collection efficiency of kerb inlet

5.17 The flow collection efficiency (η in %) is given by:

$$\eta = 100 - \frac{36.1\,Q}{L_i\,H^{1.5}} \tag{13}$$

Q is the flow rate (in m^3/s) in the kerb channel just upstream of the gully and is calculated from Section 5.13. H is the corresponding water depth (in m) at the kerb. L_i is the length (in m) of the opening in the line of the kerb provided by the inlet. Note that in the case of an angled kerb inlet (see Figure 2), L_i is greater than the length L of the kerb unit itself. For the particular kerb angles shown in Figure 2, $L_i = 3.7$ L.

5.18 If Equation (13) shows that the flow collection efficiency, η, would be less than 60%, the use of either a longer kerb inlet or a suitable gully grating is recommended (see Section 5.7).

Maximum design spacing for kerb inlets

5.19 The maximum allowable spacing between intermediate kerb inlets can be determined from the equations in Sections 5.15 and 5.16.

Effect of longitudinally varying gradient

5.20 If the longitudinal gradient of a kerb channel increases significantly with distance in the direction of flow, it is necessary to check that the channel has sufficient flow capacity at all points along its length. If the distance between two adjacent gullies is Z and the gradient at the downstream gully is S_L (see Section 5.1), then at any intermediate distance Z_i from the upstream gully the local gradient S_i should satisfy the following requirement:

$$S_i \geq S_L \, (Z_i / Z)^2 \tag{14}$$

If the limit is not satisfied, an additional gully should be located at the point where the kerb channel has insufficient capacity*.

Terminal gullies

5.21 The procedure for terminal gullies is as follows. It is not recommended that kerb inlets should be used as terminal gullies at sag points unless this is in combination with gratings.

(i) **Single gully at sag point.** There will be flow into the gully from both directions. Table C1 or Equation (9) should be used to determine which direction will give the greater flow. This flow should be doubled, and equation (10) or (13) used to determine the flow collection efficiency η, which should be greater than 95% for effective drainage. The maximum allowable spacings upstream of the gully should be checked using Equations (11) or (12).

(ii) **Twin gullies at sag point.** (Preferred option). Use the tables or equations to determine the design spacing and η for each gully. η must be greater than 95% for both gullies.

(iii) **Other terminal gullies.** The design spacing upstream of the gully, should be determined from the tables or equations. To avoid excessive flow past the gully, η should be greater than 95%.

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* Note that the limit only needs to be checked if S_i **increases** with Z_i , the opposite of what might be expected. The above requirement is independent of whether gratings or kerb inlets are used.

Calculation to check critical storm duration

5.22 A critical storm duration, T, of 5 minutes has been suggested (Section 4.13) for use in both design tables and calculations. It is desirable however to check that this assumption is valid for the shortest and longest drainage lengths between gullies.

5.23 The sum of the time taken for water to travel from the furthest point on the road surface to the kerb, t_s, and then along the kerb to the gully, t_g, should be approximately equal to T, ie:

$$T = t_s + t_g \tag{15}$$

A value of t_s of 3 minutes is normally recommended, but Ref 10 provides information on non-standard cases. For a reasonably uniform gradient, t_g (in minutes) may be calculated from the flow velocity, V (in m/s) and gully spacing:

$$t_g = S_p / 60V \tag{16}$$

where $V = 2Q / B^2 S_c$

If Equation (15) shows T to be outside the range 4 to 7 minutes, the design procedure should be repeated using the recalculated value of critical storm duration (T) rounded to the nearest minute.

Flow capacity of gully pots

5.24 On steeper sections of road, the maximum allowable spacing between gullies may not be determined by the collection efficiency of the grating but by the flow capacity of the gully pot beneath it. Experimental tests [Forty, Ref 11] indicate that the maximum flow rate that can be accepted by a gully pot without surcharge is about 10 litres/s if the outlet pipe has a diameter of 100mm, and 15 litres/s if it has a diameter of 150mm.

Redesign

5.25 If possible, the design spacings of gullies should be adjusted to be less than the allowable spacings determined from the design tables or by calculation. If, however, the spacings or grating efficiency for the scheme prove to be unsatisfactory for any reason, redesign should be considered, using one or more of the following options.

(i) If the grating efficiency η is less than about 80% for an intermediate gully, the most effective solution is likely to be redesign with an improved grating type.

(ii) If the grating efficiency η of a terminal grating is less than 95%, redesign is essential. The first step should be to redesign with an improved grating type. If the required efficiency is still not achieved, the permitted width of kerb flow B should be replaced by a lesser design width. This will have the effect of reducing the design flow approaching the grating and increasing the grating efficiency, but may require the use of additional intermediate gullies.

Some adjustment of the hydraulic parameters may also be possible, eg changes in the road profile or the catchment area.

6. WORKED EXAMPLES

Example 1: Urban motorway with non-uniform gradients

Transverse and longitudinal cross-sections of a length of 2-lane blacktop urban motorway near Reading are shown in Figure 4a. The length considered has a well-defined crest, followed by a fall to a uniform gradient of 1/30 (3.33%). For this example, the return period (N) for the design storm is taken to be 5 years, and the maximum allowable width of flow (B) to be 1.0m. A gully grating of Type R will be assumed. Maintenance is only moderate, and m in Table 2 is assumed to be 0.9. The parameters for the design calculation are therefore as follows:

Cross-fall (S_c) = 1/40 (= 2.5%)
Longitudinal gradient (S_L) as shown in Figure 4a

n	= 0.017
B	= 1.0m
T	= 5 minutes
N	= 5 years
2minM5	= 4mm (from Figure 3)
m	= 0.9
W_e	= 7.3 + 2.75 + (0.2 x 2.0)
	= 10.45 m
I	= 87mm/hr (Equation (1))

The tables in Annex C will be used for this design exercise, as described in sections 5.2 to 5.10.

Since the crest is well-defined, no gully is needed at this point. As a trial, assume the next gully is to be 20m downstream of this. Then using Table C1 (estimating that the average longitudinal gradient over the 3m upstream of the gully is 1/50);
Discharge capacity of channel = 5.5 litre/s

This discharge is sufficiently low that the flow capacity of the gully pot should not be exceeded (see section 5.24). Using Table C4:

Area drained = 344m^2 for I = 50mm/hr and m = 1.0.
Efficiency (η) = 87%, which is greater than 80% so, using Equation (2);
Actual area drained = 344 x (50/87.1) x 0.9 = 178m^2

Using Equation (4);
Maximum allowable spacing (S_p) = 178/10.45 = 17m.

Using Equations (16) and (15) to check the value of T gives V= 2 x 5.5 x 10^{-3}/(1^2 x .025) = 0.44m/s and T = 3 + 17/(60 x 0.44) = 3.6min.

This falls outside the specified range of 4 to 7 minutes so the calculation is repeated using T = 4 minutes. This gives the following new values:

I	= 94.8mm/hr.
A_a	= 344 x (50/94.8) x 0.9 = 163m^2
S_p	= 15.6m

The calculated spacing of 15.6m is substantially less than the 20m spacing assumed. In addition the table is not very accurate where there are large changes in gradient along the length (see Section 5.6).

For a second trial, a spacing of 10m will be assumed (S_L =1/150 from Figure 4a). Then, from Table C2 and following the same procedure, keeping I = 94.8mm/hr:

Actual area drained = 211 x (50/94.8) x 0.9 = 100m^2
η = 92%
S_p = 100/10.45 = 9.6m

Considering the approximations made the assumed spacing is therefore satisfactory.

Assume a spacing of 20m for subsequent gratings, ie 30m from the start, with a gradient of 1/30. This gives:

Actual area drained = 202m^2
η = 83%
S_p = 19.3m

The assumed spacing is therefore satisfactory.

Example 2: Urban single carriageway

A cross-section of the black-top single-carriageway road and footway is shown in Figure 4b. The road is in the London area with a uniform longitudinal gradient, and passes through a shopping area with a pedestrian crossing.

For such a site, the return period (T) for the design storm is 1 year, and the maximum allowable width of flow (B) is 0.5m. A gully grating of Type R will be considered initially. The gullies are assumed to be well maintained, ie m in Table 2 is 1.0. The parameters required for the calculation of gully spacing and type are therefore as follows:

S_c	= 0.03 (1/33)
S_L	= 0.025 (1/40)
n	= 0.017
B	= 0.5m
T	= 5 minutes (for initial calculation)
N	= 1 years
2minM5	= 4.0mm (from Figure 3)
G_d	= 60 s/m^2 (for initial calculation) (see Annex B)
W_e	= 6.5m
I	= 55.2 mm/hr (Equation 1)

Design will be by the calculations given in Sections 5.12 to 5.16 and 5.23.

Flow rate Q calculated from Equation (9) is 0.0013 m^3/s.

Flow collection efficiency calculated from Equation (10) is η= 95%.

The maximum allowable spacing between gullies (S_p) may then be calculated from Equation (11) for a uniform longitudinal gradient as 12.4m.

To check the initial assumption of a storm duration of 5 minutes, T may be calculated from Equations (15) and (16) as 3.6 minutes. A better estimate of the design storm duration from Equation (15) is therefore 4 minutes.

Re-calculating with this figure gives:

η = 95%

S_p = 11.4m

This is a fairly short spacing. The grating selected performs reasonably efficiently, and changing to a more efficient grating type would make little difference. A better alternative might be to install separate linear drainage for the footway, reducing the effective width W_e of the catchment to 3.5m. The maximum allowable spacing (S_p) would then improve to 21.2m.

A gully should be placed immediately upstream of the pedestrian crossing. Even for a grating of Type R, η is 95%, so the flow past the gully is small enough not to inconvenience pedestrians.

7. DEFINITIONS

Time of concentration	The sum of the time taken for water to travel from the furthest point on the road surface to the kerb, and then along the kerb to the gully.
Critical storm duration	A storm duration equal to the time of concentration.
Frame	For a gully, the fixed part of the gully top that receives and supports the grating.
Grating	The removeable part(s) of a gully top that permits the passage of water to the gully.
Gully	An assembly to receive water for discharge into a drainage system.
Gully pot	A device installed below a grating to collect settleable solids and prevent them entering the piped drainage system.
Gully top	That part of a gully which is placed on the gully pot.
Intermediate gullies	Gullies for which some calculated portion of the approaching flow may be permitted to continue past the grating, to be picked up by the next grating downstream.
Kerb channel	The channel formed by the surface of a carriageway and the kerb.
Clear area	The area encompassed by the gully frame with the grating removed.
Return period	The average period between successive exceedances of a specified storm event.
Surface water channel	A triangular or other cross-section channel near the edge of the carriageway specially constructed to collect and convey water.
Terminal gullies	Gullies for which no significant portion of the approaching flow may be permitted to pass the grating.
Waterway area	The total area of all the slots in a grating through which water can pass.
Transverse bar	Part of the grating which is at 90º ± 10º to the direction of flow.

8. REFERENCES

1 **Design Manual for Roads and Bridges (DMRB) (TSO)**

HA 37 Hydraulic Design of Road Edge Surface Water Channels (DMRB 4.2.4).

HA 39 Edge of Pavement Details (DMRB 4.2.4).

HA 78 Design of Outfalls for Surface Water Channels (DMRB 4.2.1).

HA 79 Edge of Pavement Details for Porous Asphalt Surface Covers (DMRB 4.2.4).

HA 83 Safety Aspects of Road Edge Drainage Features (DMRB 4.2.4)

HD 33 Surface and Sub-surface Drainage Systems for Highways (DMRB 4.2.3)

TA 57 Roadside Features (DMRB 6.3).

TD 9 Highway Link Design (DMRB 6.1.1).

TD 16 Geometric Design of Roundabouts (DMRB 6.2.3).

2 **Manual of Contract Documents for Highway Works (MCHW) (TSO)**

Specification for Highway Works (MCHW 1).

Notes for Guidance on the Specification for Highway Works (MCHW 2).

Highway Construction Details (MCHW 3).

3 The drainage capacity of BS road gullies and a procedure for estimating their spacing. TRRL Contractor Report 2, 1984.

4 Spaliviero F, May RWP and Escarameia M. Spacing of road gullies: Hydraulic performance of BS EN 124 gully gratings and kerb inlets. HR Wallingford, Report SR 533, 2000.

5 Trunk Road Maintenance Manual. Volume 2. Routine and Winter Maintenance Code. Highways Agency, London.

6 BS EN 124. Gully tops and manhole tops for vehicular and pedestrian areas - Design requirements, type testing, marking, quality control (British Standards Institution, London).

7 BS 7903. Guide to selection and use of gully tops and manhole covers for installation within the highway. (British Standards Institution, London).

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9 Whiffin AC and Young CP. Drainage of level or nearly level roads. TRRL Report LR 602, 1973.

10 The Wallingford Procedure: Design and analysis of urban storm drainage – Volume 1, Principles, methods and practice (in Section 7.10). National Water Council, London, 1981.

11 Forty EJ. Performance of gully pots for road drainage. HR Wallingford, Report SR 508, 1998.

12 BS 7263. Precast concrete flags, kerbs, channels, edgings and quadrants. (British Standards Institution, London).

9. ENQUIRIES

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ANNEX A LIST OF SYMBOLS

Symbol	Description	Units
A_a	As A_{dr} but for actual rainfall intensity, maintenance factor and channel roughness	m^2
A_{dr}	Maximum area which can be drained by a kerb channel for a rainfall intensity of I = 50mm/hr, a maintenance factor of m = 1.0, and a channel roughness of n = 0.017.	m^2
A_f	Cross-sectional area of flow in channel just upstream of grating	m^2
A_g	Area of smallest rectangle with two sides parallel to kerb that contains all the slots in the grating	m^2
B	Maximum allowable width of flow in channel upstream of grating	m
C_b	Coefficient for grating bar pattern	-
G	Grating parameter	s/m^2
G_d	Design value of G for grating type	s/m^2
H	Water depth at kerb	m
I	Design rainfall intensity	mm/h
k_n	Roughness and grating efficiency factor	-
k_L	Kerb inlet length factor	-
L	Length of opening provided by kerb inlet	m
L_i	Overall length of opening in kerb provided by angled kerb inlet	m
m	Maintenance factor	-
m_{us}	Maintenance factor for upstream grating	-
N	Return period of design storm	years
n	Manning roughness coefficient	-
p	Waterway area as a percentage of grating area	%
Q	Flow rate in channel approaching grating	m^3/s
Q_{us}	Flow rate in channel approaching upstream grating	m^3/s
R	Hydraulic radius of channel	m
S_c	Cross-fall	-
S_i	Longitudinal slope at distance Z_i from upstream gully	m
S_p	Maximum allowable spacing between adjacent gullies	m
S_L	Longitudinal gradient	-
T	Critical storm duration	minutes
t_g	Time for water to travel along kerb to gully grating	minutes
t_s	Time for water to travel from furthest point on road surface to kerb	minutes
V	Flow velocity along kerb	m/s
W_e	Effective catchment width draining to channel	m
η	Flow collection efficiency of grating	%
η_{us}	Flow collection efficiency of upstream grating	%
2minM5	Rainfall depth occurring at a location in a period of 2 minutes with an average return period of 5 years	mm
Z	Distance between adjacent gullies	m
Z_i	Distance from upstream gully measured in downstream direction	m

ANNEX B DETERMINING THE GRATING TYPE

B.1 The Designer should first determine the following three geometrical parameters:

- The area A_g (in m^2) of the smallest rectangle parallel to the kerb that just includes all the slots.
- The waterway area as a percentage (p) of the grating area A_g.
- The coefficient C_b determined from Table B1 below.

Grating bar pattern	**C_b**
Transverse bars	1.75
Other bar alignments - (ie longitudinal, diagonal and bars curved in plan)	1.5

Table B1 Grating bar pattern

B.2 Bars more than 10mm below the surface of the grating should be treated as part of the waterway area when calculating the value of p. If a grating has a combination of bar alignments, the number of transverse slots and the number of slots with other alignments should be calculated. If there are more transverse slots than other slots, C_b should be taken as 1.75; otherwise C_b should be taken as 1.5.

B.3 The category into which a grating falls may then be determined from the value of the grating parameter G (in s/m^2):

$$G = \frac{69\ C_b}{A_g^{0.75}\ \sqrt{p}} \qquad \text{(B.1)}$$

B.4 The grating Type and the corresponding design value G_d of the grating parameter should then be determined from Table B2. The value of G_d should be used to calculate the maximum spacing between gullies, rather than the actual value of G from Equation (B.1).

Grating type	**P**	**Q**	**R**	**S**	**T**
Range of G (s/m^2)	≤ 30	30.1 - 45	45.1 - 60	60.1 - 80	80.1 - 110
Design value G_d (s/m^2)	30	45	60	80	110

Table B2 Determination of grating type

ANNEX C DESIGN TABLES

Table C1: Discharge at the kerb in litres/s

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**			
		0.5	0.75	1	1.5
1/60	1/300	0.18	0.53	1.15	3.39
	1/150	0.26	0.76	1.63	4.80
	1/100	0.31	0.93	1.99	5.87
	1/80	0.35	1.03	2.23	6.57
	1/60	0.41	1.19	2.57	7.58
	1/50	0.44	1.31	2.82	8.31
	1/40	0.50	1.46	3.15	9.29
	1/30	0.57	1.69	3.64	10.73
	1/20	0.70	2.07	4.46	13.14
	1/15	0.81	2.39	5.14	15.17
1/50	1/300	0.24	0.72	1.56	4.59
	1/150	0.35	1.02	2.20	6.49
	1/100	0.42	1.25	2.69	7.94
	1/80	0.47	1.40	3.01	8.88
	1/60	0.55	1.62	3.48	10.25
	1/50	0.60	1.77	3.81	11.23
	1/40	0.67	1.98	4.26	12.56
	1/30	0.77	2.28	4.92	14.50
	1/20	0.95	2.80	6.02	17.76
	1/15	1.10	3.23	6.96	20.51
1/40	1/300	0.35	1.04	2.25	6.63
	1/150	0.50	1.48	3.18	9.38
	1/100	0.61	1.81	3.89	11.48
	1/80	0.69	2.02	4.35	12.84
	1/60	0.79	2.33	5.03	14.83
	1/50	0.87	2.56	5.51	16.24
	1/40	0.97	2.86	6.16	18.16
	1/30	1.12	3.30	7.11	20.97
	1/20	1.37	4.04	8.71	25.68
	1/15	1.58	4.67	10.06	29.65

Manning's coefficient is n = 0.017.
For other values of Manning's n, multiply the discharge by (0.017/n)

Table C1 (cont.): Discharge at the kerb in litres/s

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)			
		0.5	0.75	1	1.5
1/30	1/300	0.57	1.68	3.61	10.65
	1/150	0.80	2.37	5.11	15.06
	1/100	0.99	2.91	6.26	18.45
	1/80	1.10	3.25	6.99	20.62
	1/60	1.27	3.75	8.08	23.81
	1/50	1.39	4.11	8.85	26.09
	1/40	1.56	4.59	9.89	29.17
	1/30	1.80	5.30	11.42	33.68
	1/20	2.20	6.50	13.99	41.25
	1/15	2.54	7.50	16.15	47.63
1/25	1/300	0.77	2.26	4.87	14.37
	1/150	1.09	3.20	6.89	20.32
	1/100	1.33	3.92	8.44	24.88
	1/80	1.49	4.38	9.44	27.82
	1/60	1.72	5.06	10.90	32.13
	1/50	1.88	5.54	11.94	35.19
	1/40	2.10	6.20	13.35	39.35
	1/30	2.43	7.16	15.41	45.43
	1/20	2.97	8.76	18.87	55.64
	1/15	3.43	10.12	21.79	64.25
1/20	1/300	1.11	3.26	7.02	20.70
	1/150	1.56	4.61	9.93	29.28
	1/100	1.92	5.65	12.16	35.86
	1/80	2.14	6.31	13.60	40.09
	1/60	2.47	7.29	15.70	46.29
	1/50	2.71	7.99	17.20	50.71
	1/40	3.03	8.93	19.23	56.69
	1/30	3.50	10.31	22.20	65.46
	1/20	4.28	12.63	27.19	80.18
	1/15	4.95	14.58	31.40	92.58
1/15	1/300	1.77	5.21	11.22	33.07
	1/150	2.50	7.37	15.86	46.77
	1/100	3.06	9.02	19.43	57.28
	1/80	3.42	10.09	21.72	64.04
	1/60	3.95	11.65	25.08	73.94
	1/50	4.33	12.76	27.47	81.00
	1/40	4.84	14.26	30.72	90.56
	1/30	5.59	16.47	35.47	104.57
	1/20	6.84	20.17	43.44	128.07
	1/15	7.90	23.29	50.16	147.89

Manning’s coefficient is n = 0.017.
For other values of Manning’s n, multiply the discharge by (0.017/n)

Table C2: TYPE P

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	38	*(99)*	81	*(98)*	234	*(96)*
	1/150	18	*(99)*	53	*(98)*	114	*(97)*	325	*(94)*
	1/100	22	*(99)*	65	*(98)*	138	*(96)*	393	*(93)*
	1/80	25	*(99)*	73	*(98)*	154	*(96)*	436	*(92)*
	1/60	29	*(99)*	84	*(97)*	177	*(95)*	496	*(91)*
	1/50	31	*(98)*	91	*(97)*	193	*(95)*	539	*(90)*
	1/40	35	*(98)*	102	*(96)*	214	*(94)*	594	*(94)*
	1/30	40	*(98)*	117	*(96)*	245	*(93)*	673	*(87)*
	1/20	49	*(97)*	142	*(95)*	295	*(92)*	797	*(84)*
	1/15	57	*(97)*	162	*(94)*	336	*(91)*	893	*(82)*
1/50	1/300	18	*(99)*	51	*(99)*	109	*(98)*	315	*(95)*
	1/150	25	*(99)*	72	*(98)*	153	*(97)*	437	*(94)*
	1/100	30	*(99)*	88	*(97)*	186	*(96)*	526	*(92)*
	1/80	34	*(99)*	98	*(97)*	207	*(95)*	583	*(91)*
	1/60	39	*(98)*	113	*(97)*	237	*(95)*	663	*(90)*
	1/50	42	*(98)*	123	*(96)*	259	*(94)*	718	*(89)*
	1/40	47	*(98)*	137	*(96)*	287	*(94)*	791	*(87)*
	1/30	54	*(98)*	157	*(95)*	328	*(93)*	893	*(85)*
	1/20	66	*(97)*	190	*(94)*	395	*(91)*	1052	*(82)*
	1/15	76	*(97)*	218	*(94)*	449	*(90)*	1174	*(79)*
1/40	1/300	25	*(99)*	74	*(98)*	158	*(97)*	452	*(95)*
	1/150	36	*(99)*	104	*(98)*	220	*(96)*	624	*(92)*
	1/100	44	*(99)*	126	*(97)*	267	*(95)*	751	*(91)*
	1/80	49	*(98)*	141	*(97)*	297	*(95)*	829	*(90)*
	1/60	56	*(98)*	162	*(96)*	340	*(94)*	941	*(88)*
	1/50	61	*(98)*	177	*(96)*	370	*(93)*	1017	*(87)*
	1/40	68	*(98)*	196	*(95)*	411	*(93)*	1117	*(85)*
	1/30	78	*(97)*	225	*(95)*	468	*(91)*	1256	*(83)*
	1/20	96	*(97)*	272	*(94)*	562	*(90)*	1469	*(79)*
	1/15	110	*(96)*	311	*(93)*	637	*(88)*	1628	*(76)*

Manning's coefficient is n = 0.017
For others values of rainfall intensity I, multiply the area by (50/I)

Table C2 (cont.): TYPE P

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**							
		0.5		0.75		1		1.5	
1/30	1/300	41	*(99)*	118	*(98)*	252	*(97)*	718	*(94)*
	1/150	57	*(99)*	166	*(97)*	351	*(95)*	986	*(91)*
	1/100	70	*(98)*	202	*(97)*	425	*(94)*	1181	*(89)*
	1/80	78	*(98)*	225	*(96)*	472	*(94)*	1301	*(88)*
	1/60	89	*(98)*	258	*(95)*	539	*(93)*	1470	*(86)*
	1/50	98	*(97)*	281	*(95)*	586	*(92)*	1584	*(84)*
	1/40	109	*(97)*	312	*(94)*	649	*(91)*	1732	*(83)*
	1/30	125	*(97)*	358	*(94)*	738	*(90)*	1935	*(80)*
	1/20	152	*(96)*	431	*(92)*	880	*(87)*	2235	*(75)*
	1/15	175	*(95)*	491	*(91)*	994	*(85)*	2449	*(71)*
1/25	1/300	55	*(99)*	159	*(98)*	338	*(96)*	960	*(93)*
	1/150	77	*(98)*	223	*(97)*	471	*(95)*	1314	*(90)*
	1/100	94	*(98)*	271	*(96)*	569	*(94)*	1569	*(88)*
	1/80	105	*(98)*	302	*(96)*	631	*(93)*	1725	*(86)*
	1/60	120	*(97)*	346	*(95)*	720	*(92)*	1942	*(84)*
	1/50	132	*(97)*	377	*(94)*	782	*(91)*	2088	*(82)*
	1/40	147	*(97)*	419	*(94)*	865	*(90)*	2276	*(80)*
	1/30	168	*(96)*	478	*(93)*	981	*(88)*	2528	*(77)*
	1/20	204	*(96)*	576	*(91)*	1167	*(86)*	2892	*(72)*
	1/15	234	*(95)*	655	*(90)*	1313	*(84)*	3140	*(68)*
1/20	1/300	79	*(99)*	229	*(97)*	484	*(96)*	1367	*(92)*
	1/150	110	*(98)*	320	*(96)*	672	*(94)*	1861	*(88)*
	1/100	135	*(98)*	388	*(95)*	812	*(93)*	2211	*(86)*
	1/80	150	*(97)*	432	*(95)*	899	*(92)*	2423	*(84)*
	1/60	173	*(97)*	494	*(94)*	1024	*(91)*	2716	*(81)*
	1/50	189	*(97)*	538	*(94)*	1111	*(90)*	2910	*(80)*
	1/40	210	*(96)*	597	*(93)*	1225	*(88)*	3156	*(77)*
	1/30	241	*(96)*	681	*(92)*	1386	*(87)*	3479	*(74)*
	1/20	293	*(95)*	817	*(90)*	1638	*(84)*	3921	*(68)*
	1/15	335	*(94)*	927	*(88)*	1835	*(81)*	4197	*(63)*
1/15	1/300	125	*(98)*	363	*(97)*	767	*(95)*	2145	*(90)*
	1/150	176	*(98)*	507	*(96)*	1061	*(93)*	2895	*(86)*
	1/100	214	*(97)*	614	*(95)*	1276	*(91)*	3415	*(83)*
	1/80	239	*(97)*	682	*(94)*	1411	*(90)*	3725	*(81)*
	1/60	274	*(96)*	780	*(93)*	1602	*(89)*	4143	*(78)*
	1/50	299	*(96)*	848	*(92)*	1734	*(88)*	4415	*(76)*
	1/40	333	*(96)*	939	*(91)*	1906	*(86)*	4749	*(73)*
	1/30	382	*(95)*	1069	*(90)*	2146	*(84)*	5167	*(69)*
	1/20	462	*(94)*	1276	*(88)*	2516	*(80)*	5678	*(62)*
	1/15	528	*(93)*	1443	*(86)*	2796	*(77)*	5924	*(56)*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C3: TYPE Q

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	38	*(98)*	80	*(97)*	229	*(94)*
	1/150	18	*(99)*	53	*(97)*	112	*(96)*	316	*(91)*
	1/100	22	*(98)*	64	*(97)*	136	*(95)*	378	*(89)*
	1/80	25	*(98)*	72	*(96)*	151	*(94)*	417	*(88)*
	1/60	29	*(98)*	82	*(96)*	172	*(93)*	472	*(86)*
	1/50	31	*(98)*	90	*(95)*	187	*(92)*	509	*(85)*
	1/40	35	*(97)*	100	*(95)*	208	*(91)*	557	*(83)*
	1/30	40	*(97)*	114	*(94)*	236	*(90)*	623	*(81)*
	1/20	49	*(96)*	138	*(93)*	282	*(88)*	722	*(76)*
	1/15	56	*(96)*	157	*(91)*	319	*(86)*	794	*(73)*
1/50	1/300	17	*(99)*	51	*(98)*	108	*(97)*	307	*(93)*
	1/150	25	*(98)*	71	*(97)*	151	*(95)*	422	*(90)*
	1/100	30	*(98)*	87	*(96)*	182	*(94)*	504	*(88)*
	1/80	33	*(98)*	96	*(96)*	202	*(93)*	554	*(87)*
	1/60	38	*(98)*	111	*(95)*	231	*(92)*	625	*(85)*
	1/50	42	*(97)*	121	*(95)*	251	*(91)*	673	*(83)*
	1/40	47	*(97)*	134	*(94)*	277	*(90)*	734	*(81)*
	1/30	54	*(97)*	153	*(93)*	315	*(89)*	817	*(78)*
	1/20	65	*(96)*	185	*(92)*	375	*(86)*	938	*(73)*
	1/15	75	*(95)*	210	*(90)*	422	*(84)*	1022	*(69)*
1/40	1/300	25	*(99)*	73	*(97)*	155	*(96)*	439	*(92)*
	1/150	35	*(98)*	103	*(96)*	216	*(94)*	599	*(89)*
	1/100	43	*(98)*	125	*(96)*	261	*(93)*	713	*(86)*
	1/80	48	*(98)*	139	*(95)*	289	*(92)*	782	*(85)*
	1/60	55	*(97)*	159	*(94)*	329	*(91)*	878	*(82)*
	1/50	61	*(97)*	173	*(94)*	357	*(90)*	941	*(81)*
	1/40	67	*(97)*	192	*(93)*	394	*(89)*	1022	*(78)*
	1/30	77	*(96)*	219	*(92)*	446	*(87)*	1130	*(75)*
	1/20	94	*(95)*	263	*(90)*	529	*(84)*	1279	*(69)*
	1/15	108	*(94)*	299	*(89)*	593	*(82)*	1375	*(64)*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C3 (cont.): TYPE Q

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m) 0.5		0.75		1		1.5	
1/30	1/300	40	*(98)*	117	*(97)*	247	*(95)*	693	*(90)*
	1/150	57	*(98)*	163	*(96)*	342	*(93)*	937	*(86)*
	1/100	69	*(97)*	198	*(95)*	412	*(92)*	1108	*(83)*
	1/80	77	*(97)*	220	*(94)*	456	*(91)*	1209	*(81)*
	1/60	88	*(97)*	252	*(93)*	518	*(89)*	1347	*(79)*
	1/50	97	*(96)*	274	*(93)*	561	*(88)*	1437	*(77)*
	1/40	107	*(96)*	303	*(92)*	617	*(87)*	1549	*(74)*
	1/30	123	*(95)*	345	*(90)*	696	*(85)*	1690	*(70)*
	1/20	149	*(94)*	413	*(88)*	817	*(81)*	1867	*(63)*
	1/15	171	*(93)*	467	*(86)*	909	*(78)*	1959	*(57)*
1/25	1/300	54	*(98)*	157	*(97)*	332	*(95)*	923	*(89)*
	1/150	76	*(98)*	219	*(95)*	458	*(92)*	1240	*(85)*
	1/100	93	*(97)*	266	*(94)*	550	*(91)*	1457	*(81)*
	1/80	103	*(97)*	295	*(93)*	607	*(89)*	1585	*(79)*
	1/60	119	*(96)*	337	*(92)*	688	*(88)*	1756	*(76)*
	1/50	130	*(96)*	366	*(92)*	744	*(87)*	1865	*(74)*
	1/40	144	*(95)*	405	*(91)*	817	*(85)*	1997	*(70)*
	1/30	165	*(95)*	460	*(89)*	917	*(83)*	2157	*(66)*
	1/20	200	*(93)*	548	*(87)*	1070	*(79)*	2334	*(58)*
	1/15	228	*(92)*	618	*(85)*	1184	*(75)*	2397	*(52)*
1/20	1/300	78	*(98)*	226	*(96)*	474	*(94)*	1305	*(88)*
	1/150	109	*(97)*	314	*(94)*	651	*(91)*	1738	*(82)*
	1/100	133	*(97)*	379	*(93)*	780	*(89)*	2026	*(78)*
	1/80	148	*(96)*	420	*(92)*	859	*(88)*	2192	*(76)*
	1/60	170	*(96)*	479	*(91)*	971	*(86)*	2407	*(72)*
	1/50	186	*(95)*	520	*(90)*	1047	*(85)*	2540	*(70)*
	1/40	206	*(95)*	574	*(89)*	1145	*(83)*	2693	*(66)*
	1/30	236	*(94)*	650	*(88)*	1279	*(80)*	2862	*(61)*
	1/20	285	*(92)*	771	*(85)*	1479	*(76)*	2996	*(52)*
	1/15	324	*(91)*	866	*(83)*	1622	*(72)*	Not eff.	*(44)*
1/15	1/300	124	*(98)*	357	*(95)*	746	*(92)*	2027	*(85)*
	1/150	174	*(97)*	496	*(93)*	1020	*(89)*	2659	*(79)*
	1/100	211	*(96)*	597	*(92)*	1215	*(87)*	3061	*(74)*
	1/80	235	*(95)*	660	*(91)*	1335	*(85)*	3282	*(71)*
	1/60	269	*(95)*	751	*(90)*	1500	*(83)*	3552	*(67)*
	1/50	293	*(94)*	813	*(89)*	1611	*(81)*	3706	*(64)*
	1/40	326	*(93)*	895	*(87)*	1753	*(79)*	3863	*(59)*
	1/30	372	*(92)*	1010	*(85)*	1942	*(76)*	3986	*(53)*
	1/20	447	*(91)*	1189	*(82)*	2211	*(71)*	Not eff.	*(42)*
	1/15	508	*(89)*	1325	*(79)*	2389	*(66)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C4: TYPE R

Drained area of road in m² under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(99)*	37	*(97)*	79	*(96)*	224	*(92)*
	1/150	18	*(98)*	52	*(96)*	110	*(94)*	306	*(88)*
	1/100	22	*(98)*	64	*(96)*	133	*(93)*	363	*(86)*
	1/80	25	*(97)*	71	*(95)*	148	*(92)*	398	*(84)*
	1/60	28	*(97)*	81	*(94)*	168	*(91)*	447	*(82)*
	1/50	31	*(97)*	88	*(94)*	182	*(90)*	479	*(80)*
	1/40	34	*(96)*	98	*(93)*	201	*(89)*	520	*(78)*
	1/30	40	*(96)*	112	*(92)*	228	*(87)*	573	*(74)*
	1/20	48	*(95)*	134	*(90)*	269	*(84)*	648	*(68)*
	1/15	55	*(94)*	152	*(89)*	302	*(81)*	695	*(64)*
1/50	1/300	17	*(99)*	51	*(97)*	107	*(95)*	300	*(91)*
	1/150	24	*(98)*	71	*(96)*	148	*(93)*	406	*(87)*
	1/100	30	*(97)*	86	*(95)*	178	*(92)*	481	*(84)*
	1/80	33	*(97)*	95	*(94)*	197	*(91)*	526	*(82)*
	1/60	38	*(97)*	109	*(94)*	224	*(90)*	587	*(79)*
	1/50	42	*(96)*	118	*(93)*	243	*(89)*	627	*(78)*
	1/40	46	*(96)*	131	*(92)*	268	*(87)*	677	*(75)*
	1/30	53	*(95)*	149	*(91)*	302	*(85)*	741	*(71)*
	1/20	64	*(94)*	179	*(89)*	355	*(82)*	825	*(64)*
	1/15	74	*(93)*	203	*(87)*	396	*(79)*	871	*(59)*
1/40	1/300	25	*(98)*	73	*(97)*	153	*(95)*	427	*(89)*
	1/150	35	*(98)*	101	*(95)*	211	*(92)*	574	*(85)*
	1/100	43	*(97)*	123	*(94)*	254	*(91)*	675	*(82)*
	1/80	48	*(97)*	136	*(94)*	281	*(90)*	735	*(79)*
	1/60	55	*(96)*	156	*(93)*	318	*(88)*	814	*(76)*
	1/50	60	*(96)*	169	*(92)*	344	*(87)*	865	*(74)*
	1/40	67	*(95)*	187	*(91)*	378	*(85)*	928	*(71)*
	1/30	76	*(95)*	213	*(89)*	425	*(83)*	1003	*(66)*
	1/20	92	*(93)*	253	*(87)*	496	*(79)*	1089	*(59)*
	1/15	105	*(92)*	286	*(85)*	549	*(76)*	1122	*(53)*

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C4 (cont.): TYPE R

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**							
		0.5		0.75		1		1.5	
1/30	1/300	40	*(98)*	116	*(96)*	243	*(93)*	669	*(87)*
	1/150	56	*(97)*	161	*(94)*	334	*(91)*	888	*(82)*
	1/100	68	*(96)*	195	*(93)*	400	*(89)*	1034	*(78)*
	1/80	76	*(96)*	216	*(92)*	440	*(87)*	1117	*(75)*
	1/60	87	*(95)*	246	*(91)*	497	*(85)*	1225	*(71)*
	1/50	95	*(95)*	267	*(90)*	536	*(84)*	1290	*(69)*
	1/40	106	*(94)*	294	*(89)*	585	*(82)*	1365	*(65)*
	1/30	121	*(94)*	333	*(87)*	653	*(79)*	1445	*(60)*
	1/20	146	*(92)*	395	*(84)*	754	*(75)*	1500	*(51)*
	1/15	166	*(91)*	443	*(82)*	825	*(71)*	Not eff.	*(43)*
1/25	1/300	54	*(98)*	156	*(95)*	325	*(93)*	886	*(86)*
	1/150	76	*(97)*	216	*(94)*	445	*(90)*	1166	*(80)*
	1/100	92	*(96)*	260	*(92)*	531	*(87)*	1346	*(75)*
	1/80	102	*(96)*	288	*(91)*	583	*(86)*	1446	*(72)*
	1/60	117	*(95)*	327	*(90)*	656	*(84)*	1570	*(68)*
	1/50	128	*(94)*	355	*(89)*	706	*(82)*	1642	*(65)*
	1/40	142	*(94)*	391	*(88)*	769	*(80)*	1718	*(61)*
	1/30	162	*(93)*	441	*(86)*	853	*(77)*	1785	*(55)*
	1/20	195	*(91)*	520	*(82)*	974	*(72)*	Not eff.	*(44)*
	1/15	222	*(90)*	581	*(80)*	1056	*(67)*		
1/20	1/300	78	*(97)*	222	*(95)*	463	*(92)*	1244	*(83)*
	1/150	108	*(96)*	307	*(93)*	630	*(88)*	1614	*(77)*
	1/100	132	*(95)*	370	*(91)*	748	*(85)*	1841	*(71)*
	1/80	146	*(95)*	409	*(90)*	819	*(84)*	1961	*(68)*
	1/60	167	*(94)*	464	*(88)*	917	*(81)*	2099	*(63)*
	1/50	182	*(93)*	502	*(87)*	983	*(79)*	2170	*(59)*
	1/40	202	*(93)*	551	*(86)*	1065	*(77)*	2231	*(55)*
	1/30	231	*(92)*	620	*(84)*	1173	*(73)*	Not eff.	*(48)*
	1/20	277	*(90)*	725	*(80)*	1319	*(67)*		
	1/15	314	*(88)*	805	*(77)*	1409	*(62)*		
1/15	1/300	123	*(97)*	352	*(94)*	726	*(90)*	1909	*(80)*
	1/150	172	*(96)*	483	*(91)*	979	*(86)*	2422	*(72)*
	1/100	208	*(94)*	579	*(89)*	1154	*(83)*	2707	*(66)*
	1/80	231	*(94)*	638	*(88)*	1258	*(80)*	2839	*(62)*
	1/60	264	*(93)*	721	*(86)*	1398	*(77)*	2962	*(56)*
	1/50	287	*(92)*	778	*(85)*	1489	*(75)*	2998	*(51)*
	1/40	318	*(91)*	851	*(83)*	1600	*(72)*	Not eff.	*(46)*
	1/30	362	*(90)*	951	*(80)*	1739	*(68)*		
	1/20	432	*(88)*	1101	*(76)*	1905	*(61)*		
	1/15	488	*(86)*	1208	*(72)*	1981	*(55)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C5: TYPE S

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m) 0.5		0.75		1		1.5	
1/60	1/300	13	*(98)*	37	*(97)*	78	*(94)*	218	*(89)*
	1/150	18	*(98)*	52	*(95)*	108	*(92)*	292	*(85)*
	1/100	22	*(97)*	63	*(94)*	130	*(90)*	343	*(81)*
	1/80	24	*(97)*	70	*(93)*	143	*(89)*	374	*(79)*
	1/60	28	*(96)*	79	*(92)*	162	*(88)*	414	*(76)*
	1/50	31	*(96)*	86	*(92)*	175	*(86)*	439	*(73)*
	1/40	34	*(95)*	95	*(91)*	193	*(85)*	470	*(70)*
	1/30	39	*(94)*	108	*(89)*	216	*(83)*	507	*(66)*
	1/20	47	*(93)*	129	*(87)*	252	*(79)*	548	*(58)*
	1/15	54	*(92)*	146	*(85)*	279	*(75)*	562	*(51)*
1/50	1/300	17	*(98)*	50	*(96)*	105	*(94)*	290	*(88)*
	1/150	24	*(97)*	70	*(95)*	144	*(91)*	386	*(83)*
	1/100	30	*(97)*	84	*(93)*	173	*(89)*	451	*(79)*
	1/80	33	*(96)*	93	*(93)*	191	*(88)*	488	*(76)*
	1/60	38	*(96)*	106	*(91)*	216	*(86)*	536	*(73)*
	1/50	41	*(95)*	115	*(91)*	233	*(85)*	567	*(70)*
	1/40	46	*(95)*	127	*(89)*	254	*(83)*	601	*(67)*
	1/30	52	*(94)*	144	*(88)*	284	*(80)*	640	*(61)*
	1/20	63	*(92)*	171	*(85)*	329	*(76)*	673	*(53)*
	1/15	72	*(91)*	193	*(83)*	361	*(72)*	Not eff.	*(45)*
1/40	1/300	25	*(98)*	72	*(96)*	150	*(93)*	410	*(86)*
	1/150	35	*(97)*	100	*(94)*	206	*(90)*	540	*(80)*
	1/100	42	*(96)*	120	*(92)*	245	*(88)*	624	*(76)*
	1/80	47	*(96)*	133	*(91)*	270	*(86)*	671	*(73)*
	1/60	54	*(95)*	151	*(90)*	304	*(84)*	730	*(68)*
	1/50	59	*(94)*	164	*(89)*	327	*(82)*	764	*(65)*
	1/40	65	*(94)*	181	*(88)*	356	*(80)*	801	*(61)*
	1/30	75	*(93)*	204	*(86)*	395	*(77)*	834	*(55)*
	1/20	90	*(91)*	241	*(83)*	452	*(72)*	Not eff.	*(45)*
	1/15	102	*(90)*	269	*(80)*	491	*(68)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C5 (cont.): TYPE S

Drained area of road in m² under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**							
		0.5		0.75		1		1.5	
1/30	1/300	40	*(97)*	114	*(95)*	238	*(91)*	636	*(83)*
	1/150	56	*(96)*	158	*(92)*	323	*(88)*	823	*(76)*
	1/100	68	*(95)*	190	*(91)*	383	*(85)*	936	*(70)*
	1/80	75	*(95)*	210	*(90)*	419	*(83)*	995	*(67)*
	1/60	86	*(94)*	238	*(88)*	469	*(81)*	1061	*(62)*
	1/50	94	*(93)*	257	*(87)*	502	*(79)*	1094	*(58)*
	1/40	104	*(93)*	282	*(85)*	543	*(76)*	1120	*(53)*
	1/30	118	*(91)*	317	*(83)*	597	*(73)*	Not eff.	*(46)*
	1/20	142	*(89)*	370	*(79)*	669	*(66)*		
	1/15	161	*(88)*	410	*(76)*	712	*(61)*		
1/25	1/300	54	*(97)*	153	*(94)*	317	*(90)*	836	*(81)*
	1/150	75	*(96)*	211	*(91)*	428	*(86)*	1067	*(73)*
	1/100	91	*(95)*	253	*(90)*	505	*(83)*	1197	*(67)*
	1/80	101	*(94)*	279	*(88)*	551	*(81)*	1260	*(63)*
	1/60	115	*(93)*	315	*(87)*	614	*(78)*	1322	*(57)*
	1/50	125	*(92)*	340	*(85)*	654	*(76)*	1345	*(53)*
	1/40	139	*(92)*	372	*(83)*	704	*(73)*	Not eff.	*(48)*
	1/30	158	*(90)*	417	*(81)*	768	*(69)*		
	1/20	189	*(88)*	484	*(77)*	846	*(62)*		
	1/15	213	*(86)*	532	*(73)*	885	*(56)*		
1/20	1/300	77	*(96)*	218	*(93)*	449	*(89)*	1161	*(78)*
	1/150	107	*(95)*	299	*(90)*	601	*(84)*	1450	*(69)*
	1/100	129	*(94)*	358	*(88)*	705	*(81)*	1594	*(62)*
	1/80	144	*(93)*	393	*(87)*	766	*(78)*	1652	*(57)*
	1/60	164	*(92)*	443	*(84)*	846	*(75)*	1687	*(51)*
	1/50	178	*(91)*	477	*(83)*	898	*(72)*	Not eff.	*(46)*
	1/40	197	*(90)*	520	*(81)*	959	*(69)*		
	1/30	224	*(89)*	579	*(78)*	1031	*(64)*		
	1/20	266	*(86)*	664	*(73)*	1106	*(56)*		
	1/15	300	*(84)*	723	*(69)*	Not eff.	*(50)*		
1/15	1/300	122	*(96)*	344	*(92)*	699	*(87)*	1751	*(74)*
	1/150	169	*(94)*	468	*(88)*	925	*(81)*	2107	*(63)*
	1/100	204	*(93)*	556	*(86)*	1073	*(77)*	2234	*(54)*
	1/80	226	*(92)*	609	*(84)*	1156	*(74)*	Not eff.	*(49)*
	1/60	257	*(91)*	682	*(81)*	1262	*(70)*		
	1/50	279	*(90)*	731	*(80)*	1326	*(67)*		
	1/40	308	*(88)*	793	*(77)*	1396	*(63)*		
	1/30	348	*(87)*	873	*(74)*	1467	*(57)*		
	1/20	412	*(84)*	984	*(68)*	Not eff.	*(48)*		
	1/15	461	*(81)*	1052	*(63)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C6: TYPE T

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/60	1/300	13	*(98)*	37	*(95)*	77	*(92)*	208	*(85)*
	1/150	18	*(97)*	51	*(93)*	105	*(89)*	272	*(79)*
	1/100	22	*(96)*	61	*(92)*	125	*(87)*	314	*(74)*
	1/80	24	*(95)*	68	*(91)*	137	*(85)*	336	*(71)*
	1/60	28	*(95)*	77	*(89)*	154	*(83)*	364	*(67)*
	1/50	30	*(94)*	83	*(88)*	165	*(81)*	380	*(63)*
	1/40	33	*(93)*	92	*(87)*	180	*(79)*	395	*(59)*
	1/30	38	*(92)*	104	*(85)*	199	*(76)*	408	*(53)*
	1/20	46	*(91)*	122	*(82)*	226	*(71)*	Not eff.	*(42)*
	1/15	52	*(89)*	136	*(79)*	245	*(66)*		
1/50	1/300	17	*(97)*	49	*(95)*	102	*(91)*	275	*(83)*
	1/150	24	*(96)*	68	*(93)*	139	*(88)*	356	*(76)*
	1/100	29	*(95)*	82	*(91)*	165	*(85)*	405	*(71)*
	1/80	32	*(95)*	90	*(90)*	181	*(83)*	431	*(67)*
	1/60	37	*(94)*	103	*(88)*	203	*(81)*	461	*(62)*
	1/50	40	*(93)*	111	*(87)*	217	*(79)*	476	*(59)*
	1/40	45	*(93)*	122	*(85)*	235	*(77)*	488	*(54)*
	1/30	51	*(91)*	137	*(83)*	258	*(73)*	Not eff.	*(47)*
	1/20	61	*(90)*	160	*(79)*	290	*(67)*		
	1/15	69	*(88)*	177	*(76)*	309	*(62)*		
1/40	1/300	25	*(97)*	71	*(94)*	146	*(90)*	385	*(81)*
	1/150	34	*(96)*	97	*(91)*	197	*(86)*	489	*(72)*
	1/100	42	*(95)*	116	*(89)*	232	*(83)*	548	*(66)*
	1/80	46	*(94)*	128	*(88)*	253	*(81)*	576	*(62)*
	1/60	53	*(93)*	145	*(86)*	282	*(78)*	603	*(57)*
	1/50	58	*(92)*	157	*(85)*	300	*(76)*	612	*(52)*
	1/40	64	*(91)*	171	*(83)*	323	*(73)*	Not eff.	*(47)*
	1/30	73	*(90)*	192	*(81)*	352	*(69)*		
	1/20	87	*(88)*	222	*(76)*	387	*(62)*		
	1/15	98	*(86)*	244	*(73)*	404	*(56)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C6 (cont.): TYPE T

Drained area of road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m) 0.5		0.75		1		1.5	
1/30	1/300	39	*(96)*	112	*(93)*	229	*(88)*	587	*(77)*
	1/150	55	*(95)*	153	*(90)*	306	*(83)*	725	*(67)*
	1/100	66	*(93)*	182	*(87)*	357	*(79)*	789	*(59)*
	1/80	74	*(93)*	200	*(86)*	387	*(77)*	811	*(55)*
	1/60	84	*(92)*	225	*(83)*	427	*(73)*	Not eff.	*(48)*
	1/50	91	*(91)*	242	*(82)*	451	*(71)*		
	1/40	101	*(90)*	264	*(80)*	480	*(67)*		
	1/30	114	*(88)*	293	*(77)*	512	*(62)*		
	1/20	136	*(85)*	334	*(71)*	542	*(54)*		
	1/15	152	*(83)*	362	*(67)*	Not eff.	*(47)*		
1/25	1/300	53	*(96)*	149	*(92)*	304	*(87)*	762	*(74)*
	1/150	73	*(94)*	203	*(88)*	402	*(81)*	918	*(63)*
	1/100	89	*(93)*	242	*(86)*	467	*(77)*	974	*(54)*
	1/80	98	*(92)*	265	*(84)*	503	*(74)*	Not eff.	*(49)*
	1/60	112	*(91)*	297	*(81)*	549	*(70)*		
	1/50	121	*(90)*	318	*(80)*	577	*(67)*		
	1/40	134	*(88)*	345	*(77)*	608	*(63)*		
	1/30	151	*(87)*	380	*(74)*	639	*(58)*		
	1/20	179	*(84)*	428	*(68)*	Not eff.	*(48)*		
	1/15	200	*(81)*	458	*(63)*				
1/20	1/300	76	*(95)*	212	*(90)*	427	*(85)*	1038	*(70)*
	1/150	105	*(93)*	287	*(86)*	559	*(78)*	1203	*(57)*
	1/100	126	*(92)*	339	*(83)*	641	*(73)*	Not eff.	*(47)*
	1/80	140	*(91)*	370	*(81)*	686	*(70)*		
	1/60	159	*(89)*	413	*(79)*	740	*(65)*		
	1/50	172	*(88)*	440	*(77)*	770	*(62)*		
	1/40	189	*(87)*	474	*(74)*	799	*(58)*		
	1/30	213	*(85)*	518	*(70)*	818	*(51)*		
	1/20	250	*(81)*	572	*(63)*	Not eff.	*(40)*		
	1/15	279	*(78)*	601	*(57)*				
1/15	1/300	120	*(94)*	332	*(89)*	658	*(81)*	1515	*(64)*
	1/150	165	*(92)*	444	*(84)*	843	*(74)*	Not eff.	*(49)*
	1/100	198	*(90)*	521	*(80)*	950	*(68)*		
	1/80	218	*(89)*	565	*(78)*	1003	*(64)*		
	1/60	247	*(87)*	624	*(74)*	1058	*(59)*		
	1/50	267	*(86)*	661	*(72)*	1081	*(55)*		
	1/40	293	*(84)*	705	*(69)*	Not eff.	*(49)*		
	1/30	328	*(82)*	756	*(64)*				
	1/20	381	*(77)*	808	*(56)*				
	1/15	420	*(74)*	Not eff.	*(49)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C7: KERB INLET WITH OPENING LENGTH EQUAL TO 0.5m

Drained area of the road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**					
		0.5		0.75		1	
1/60	1/300	11	*(83)*	28	*(72)*	51	*(61)*
	1/150	14	*(76)*	33	*(61)*	Not eff.	*(45)*
	1/100	16	*(70)*	35	*(52)*		
	1/80	17	*(67)*	Not eff.	*(46)*		
	1/60	18	*(62)*				
	1/50	18	*(58)*				
	1/40	19	*(53)*				
	1/30	Not eff.	*(46)*				
	1/20						
	1/15						
1/50	1/300	15	*(82)*	38	*(72)*	68	*(60)*
	1/150	19	*(75)*	44	*(60)*	Not eff.	*(44)*
	1/100	21	*(69)*	46	*(51)*		
	1/80	22	*(66)*	Not eff.	*(45)*		
	1/60	24	*(60)*				
	1/50	24	*(57)*				
	1/40	25	*(52)*				
	1/30	Not eff.	*(44)*				
	1/20						
	1/15						
1/40	1/300	21	*(82)*	53	*(71)*	95	*(59)*
	1/150	27	*(74)*	62	*(58)*	Not eff.	*(42)*
	1/100	30	*(68)*	Not eff.	*(49)*		
	1/80	32	*(64)*				
	1/60	34	*(59)*				
	1/50	34	*(55)*				
	1/40	35	*(50)*				
	1/30	Not eff.	*(42)*				
	1/20						
	1/15						

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

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Table C7 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 0.5m

Drained area of the road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)					
		0.5		0.75		1	
1/30	1/300	33	*(81)*	84	*(69)*	149	*(57)*
	1/150	42	*(73)*	97	*(57)*	Not eff.	*(39)*
	1/100	47	*(67)*	Not eff.	*(47)*		
	1/80	50	*(63)*				
	1/60	52	*(57)*				
	1/50	54	*(52)*				
	1/40	Not eff.	*(47)*				
	1/30						
	1/20						
	1/15						
1/25	1/300	44	*(80)*	112	*(68)*	196	*(56)*
	1/150	56	*(72)*	128	*(56)*	Not eff.	*(38)*
	1/100	63	*(66)*	Not eff.	*(46)*		
	1/80	66	*(62)*				
	1/60	69	*(56)*				
	1/50	70	*(52)*				
	1/40	Not eff.	*(46)*				
	1/30						
	1/20						
	1/15						
1/20	1/300	64	*(80)*	159	*(68)*	276	*(55)*
	1/150	80	*(71)*	180	*(54)*	Not eff.	*(36)*
	1/100	90	*(65)*	Not eff.	*(44)*		
	1/80	94	*(61)*				
	1/60	98	*(55)*				
	1/50	98	*(50)*				
	1/40	Not eff.	*(45)*				
	1/30						
	1/20						
	1/15						
1/15	1/300	100	*(79)*	249	*(66)*	427	*(53)*
	1/150	126	*(70)*	278	*(52)*	Not eff.	*(33)*
	1/100	140	*(64)*	Not eff.	*(42)*		
	1/80	146	*(59)*				
	1/60	151	*(53)*				
	1/50	Not eff.	*(49)*				
	1/40						
	1/30						
	1/20						
	1/15						

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C8: KERB INLET WITH OPENING LENGTH EQUAL TO 1.5m

Drained area of the road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/60	1/300	12	*(94)*	35	*(91)*	72	*(87)*	194	*(79)*
	1/150	17	*(92)*	47	*(87)*	96	*(82)*	244	*(71)*
	1/100	20	*(90)*	56	*(84)*	111	*(78)*	272	*(64)*
	1/80	22	*(89)*	61	*(82)*	121	*(75)*	284	*(60)*
	1/60	25	*(87)*	68	*(79)*	132	*(71)*	294	*(54)*
	1/50	27	*(86)*	73	*(77)*	139	*(68)*	Not eff.	*(49)*
	1/40	30	*(84)*	79	*(75)*	147	*(65)*		
	1/30	34	*(82)*	86	*(71)*	155	*(59)*		
	1/20	39	*(78)*	96	*(64)*	161	*(50)*		
	1/15	43	*(74)*	101	*(59)*	Not eff.	*(42)*		
1/50	1/300	17	*(94)*	47	*(90)*	97	*(87)*	260	*(79)*
	1/150	23	*(92)*	64	*(87)*	129	*(81)*	326	*(70)*
	1/100	27	*(90)*	75	*(84)*	149	*(77)*	361	*(63)*
	1/80	30	*(89)*	82	*(82)*	161	*(74)*	376	*(58)*
	1/60	34	*(87)*	92	*(79)*	176	*(70)*	387	*(52)*
	1/50	37	*(86)*	98	*(77)*	185	*(68)*	Not eff.	*(48)*
	1/40	40	*(84)*	105	*(74)*	195	*(64)*		
	1/30	45	*(81)*	115	*(70)*	206	*(58)*		
	1/20	53	*(77)*	128	*(63)*	Not eff.	*(49)*		
	1/15	58	*(74)*	134	*(58)*				
1/40	1/300	24	*(94)*	68	*(90)*	140	*(86)*	372	*(78)*
	1/150	33	*(91)*	92	*(86)*	185	*(81)*	465	*(69)*
	1/100	40	*(89)*	108	*(83)*	214	*(76)*	512	*(62)*
	1/80	44	*(88)*	118	*(81)*	230	*(73)*	531	*(57)*
	1/60	49	*(86)*	131	*(78)*	251	*(69)*	540	*(51)*
	1/50	53	*(85)*	140	*(76)*	263	*(66)*	Not eff.	*(46)*
	1/40	58	*(83)*	150	*(73)*	277	*(62)*		
	1/30	66	*(81)*	164	*(69)*	291	*(57)*		
	1/20	75	*(76)*	181	*(62)*	Not eff.	*(47)*		
	1/15	83	*(73)*	189	*(56)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C8 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 1.5m

Drained area of the road in m^2 under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	**Gradient (S_L)**	**Flow width (B in m)**							
		0.5		0.75		1		1.5	
1/30	1/300	38	*(93)*	108	*(89)*	223	*(86)*	591	*(77)*
	1/150	53	*(91)*	146	*(86)*	293	*(80)*	732	*(68)*
	1/100	63	*(89)*	172	*(82)*	339	*(79)*	800	*(60)*
	1/80	70	*(88)*	187	*(80)*	364	*(72)*	825	*(56)*
	1/60	78	*(86)*	208	*(77)*	396	*(68)*	Not eff.	*(49)*
	1/50	85	*(84)*	222	*(75)*	414	*(65)*		
	1/40	93	*(82)*	238	*(72)*	433	*(61)*		
	1/30	103	*(80)*	258	*(68)*	450	*(55)*		
	1/20	120	*(75)*	283	*(60)*	Not eff.	*(45)*		
	1/15	131	*(72)*	293	*(54)*				
1/25	1/300	51	*(93)*	146	*(90)*	300	*(85)*	791	*(76)*
	1/150	71	*(91)*	196	*(85)*	393	*(79)*	976	*(67)*
	1/100	85	*(89)*	231	*(82)*	453	*(74)*	1061	*(59)*
	1/80	93	*(87)*	251	*(80)*	486	*(72)*	1090	*(54)*
	1/60	106	*(85)*	279	*(76)*	529	*(67)*	Not eff.	*(47)*
	1/50	114	*(84)*	296	*(74)*	550	*(64)*		
	1/40	124	*(82)*	318	*(70)*	575	*(60)*		
	1/30	138	*(79)*	344	*(67)*	595	*(54)*		
	1/20	158	*(74)*	375	*(59)*	Not eff.	*(43)*		
	1/15	175	*(71)*	387	*(53)*				
1/20	1/300	74	*(93)*	209	*(89)*	429	*(85)*	1129	*(76)*
	1/150	102	*(90)*	281	*(85)*	562	*(79)*	1384	*(66)*
	1/100	122	*(88)*	330	*(81)*	646	*(74)*	1496	*(58)*
	1/80	134	*(87)*	359	*(79)*	692	*(71)*	1529	*(53)*
	1/60	151	*(85)*	398	*(76)*	748	*(66)*	Not eff.	*(46)*
	1/50	163	*(83)*	422	*(74)*	779	*(63)*		
	1/40	178	*(82)*	452	*(70)*	811	*(59)*		
	1/30	198	*(79)*	488	*(66)*	834	*(52)*		
	1/20	228	*(74)*	528	*(58)*	Not eff.	*(41)*		
	1/15	249	*(70)*	542	*(52)*				
1/15	1/300	118	*(93)*	333	*(89)*	681	*(84)*	1781	*(75)*
	1/150	162	*(90)*	446	*(84)*	888	*(77)*	2168	*(64)*
	1/100	194	*(88)*	523	*(81)*	1018	*(72)*	2324	*(56)*
	1/80	213	*(86)*	568	*(78)*	1088	*(68)*	2361	*(51)*
	1/60	240	*(84)*	628	*(75)*	1171	*(63)*	Not eff.	*(44)*
	1/50	240	*(83)*	666	*(72)*	1261	*(55)*		
	1/40	282	*(81)*	711	*(69)*	1286	*(50)*		
	1/30	313	*(78)*	765	*(64)*	Not eff.	*(39)*		
	1/20	359	*(73)*	821	*(56)*				
	1/15	391	*(69)*	Not eff.	*(49)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C9: KERB INLET WITH OPENING LENGTH EQUAL TO 1.85m

Drained area of the road in m² under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/60	1/300	12	*(95)*	36	*(92)*	74	*(90)*	203	*(83)*
	1/150	17	*(93)*	49	*(89)*	100	*(85)*	264	*(76)*
	1/100	21	*(92)*	58	*(87)*	118	*(82)*	300	*(71)*
	1/80	23	*(91)*	64	*(86)*	128	*(80)*	319	*(68)*
	1/60	26	*(90)*	72	*(83)*	142	*(77)*	341	*(62)*
	1/50	28	*(89)*	77	*(82)*	151	*(74)*	353	*(59)*
	1/40	32	*(87)*	84	*(80)*	162	*(71)*	362	*(54)*
	1/30	35	*(85)*	93	*(76)*	175	*(67)*	Not eff.	*(47)*
	1/20	41	*(82)*	106	*(71)*	191	*(60)*		
	1/15	46	*(79)*	115	*(67)*	197	*(53)*		
1/50	1/300	17	*(95)*	48	*(92)*	100	*(89)*	273	*(83)*
	1/150	23	*(93)*	66	*(89)*	134	*(85)*	353	*(76)*
	1/100	28	*(92)*	78	*(87)*	158	*(81)*	402	*(70)*
	1/80	31	*(91)*	85	*(86)*	172	*(79)*	426	*(67)*
	1/60	35	*(89)*	96	*(83)*	190	*(76)*	454	*(61)*
	1/50	38	*(88)*	103	*(81)*	202	*(74)*	467	*(58)*
	1/40	42	*(87)*	112	*(79)*	216	*(70)*	477	*(53)*
	1/30	47	*(85)*	124	*(76)*	234	*(66)*	Not eff.	*(45)*
	1/20	56	*(81)*	142	*(70)*	253	*(58)*		
	1/15	62	*(79)*	153	*(66)*	260	*(52)*		
1/40	1/300	24	*(95)*	69	*(92)*	144	*(89)*	392	*(82)*
	1/150	34	*(93)*	94	*(89)*	193	*(84)*	505	*(75)*
	1/100	40	*(91)*	112	*(86)*	226	*(81)*	571	*(69)*
	1/80	45	*(90)*	123	*(85)*	246	*(78)*	605	*(65)*
	1/60	51	*(89)*	138	*(82)*	272	*(75)*	642	*(60)*
	1/50	55	*(88)*	148	*(80)*	289	*(73)*	658	*(56)*
	1/40	60	*(86)*	161	*(78)*	308	*(70)*	668	*(51)*
	1/30	68	*(84)*	178	*(75)*	332	*(65)*	Not eff.	*(44)*
	1/20	80	*(81)*	202	*(69)*	357	*(60)*		
	1/15	89	*(78)*	217	*(64)*	364	*(50)*		

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

Table C9 (cont.): KERB INLET WITH OPENING LENGTH EQUAL TO 1.85m

Drained area of the road in m² under a rainfall intensity of 50mm/h and collection efficiency in % (in brackets)

Crossfall (S_c)	Gradient (S_L)	Flow width (B in m)							
		0.5		0.75		1		1.5	
1/30	1/300	39	*(95)*	111	*(91)*	230	*(88)*	624	*(81)*
	1/150	54	*(93)*	151	*(88)*	308	*(84)*	799	*(74)*
	1/100	65	*(91)*	179	*(86)*	360	*(80)*	900	*(68)*
	1/80	71	*(90)*	196	*(84)*	390	*(76)*	950	*(64)*
	1/60	81	*(88)*	220	*(81)*	431	*(74)*	1001	*(58)*
	1/50	88	*(87)*	236	*(80)*	456	*(72)*	1022	*(54)*
	1/40	96	*(86)*	256	*(77)*	486	*(68)*	Not eff.	*(49)*
	1/30	108	*(84)*	282	*(74)*	521	*(63)*		
	1/20	127	*(80)*	318	*(68)*	555	*(55)*		
	1/15	141	*(77)*	340	*(63)*	Not eff.	*(48)*		
1/25	1/300	52	*(95)*	149	*(92)*	309	*(88)*	837	*(81)*
	1/150	72	*(92)*	203	*(88)*	413	*(83)*	1068	*(73)*
	1/100	87	*(90)*	241	*(85)*	482	*(79)*	1199	*(67)*
	1/80	96	*(90)*	264	*(84)*	523	*(77)*	1263	*(63)*
	1/60	109	*(88)*	295	*(81)*	576	*(73)*	1326	*(57)*
	1/50	118	*(87)*	316	*(79)*	609	*(71)*	1349	(53)
	1/40	129	*(85)*	342	*(77)*	648	*(67)*	Not eff	*(48)*
	1/30	145	*(83)*	377	*(73)*	692	*(62)*		
	1/20	170	*(79)*	423	*(67)*	732	*(54)*		
	1/15	188	*(76)*	451	*(62)*	Not eff	*(47)*		
1/20	1/300	75	*(95)*	215	*(91)*	444	*(88)*	1197	*(80)*
	1/150	104	*(92)*	291	*(88)*	591	*(83)*	1521	*(72)*
	1/100	125	*(90)*	345	*(85)*	690	*(79)*	1701	*(66)*
	1/80	138	*(89)*	377	*(83)*	746	*(76)*	1786	*(62)*
	1/60	156	*(88)*	422	*(80)*	820	*(72)*	1866	*(56)*
	1/50	169	*(87)*	452	*(78)*	866	*(70)*	1890	*(52)*
	1/40	185	*(85)*	488	*(76)*	919	*(66)*	Not eff	*(46)*
	1/30	208	*(83)*	536	*(72)*	979	*(61)*		
	1/20	243	*(79)*	600	*(66)*	1028	*(52)*		
	1/15	269	*(76)*	638	*(61)*	Not eff	*(45)*		
1/15	1/300	120	*(94)*	341	*(91)*	705	*(87)*	1895	*(80)*
	1/150	165	*(92)*	462	*(87)*	936	*(82)*	2395	*(71)*
	1/100	199	*(90)*	547	*(84)*	1090	*(78)*	2665	*(65)*
	1/80	219	*(89)*	598	*(82)*	1178	*(75)*	2787	*(60)*
	1/60	248	*(87)*	668	*(80)*	1292	*(72)*	2893	*(54)*
	1/50	268	*(86)*	714	*(78)*	1441	*(65)*	Not eff	*(44)*
	1/40	294	*(84)*	771	*(75)*	1526	*(60)*		
	1/30	330	*(82)*	845	*(71)*	1586	*(51)*		
	1/20	384	*(78)*	941	*(65)*	Not eff	*(43)*		
	1/15	424	*(75)*	995	*(59)*				

Manning's coefficient is n = 0.017
For other values of rainfall intensity I, multiply the area by (50/I)

ANNEX D FIGURES

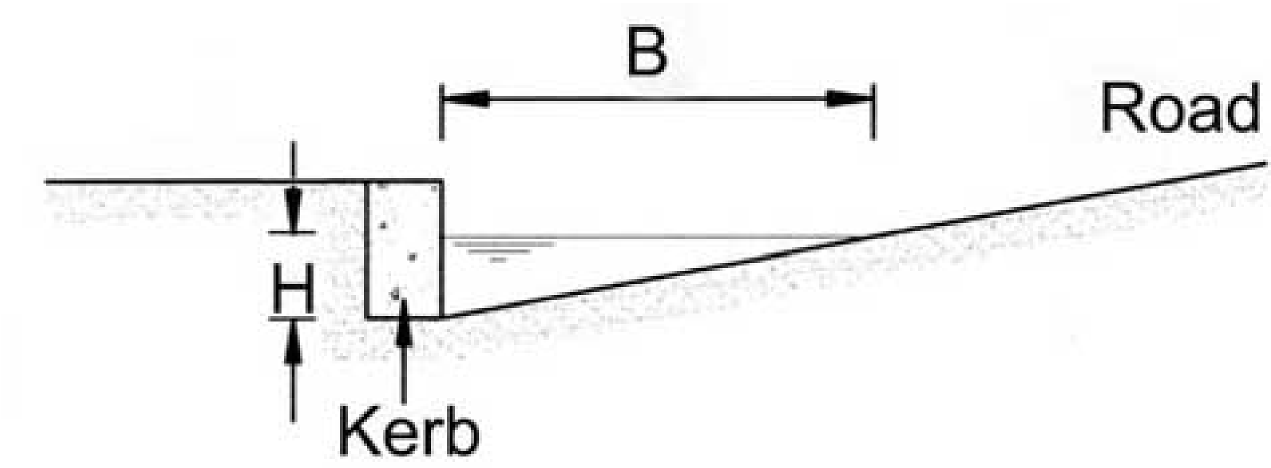

Figure 1a Depth of water against kerb

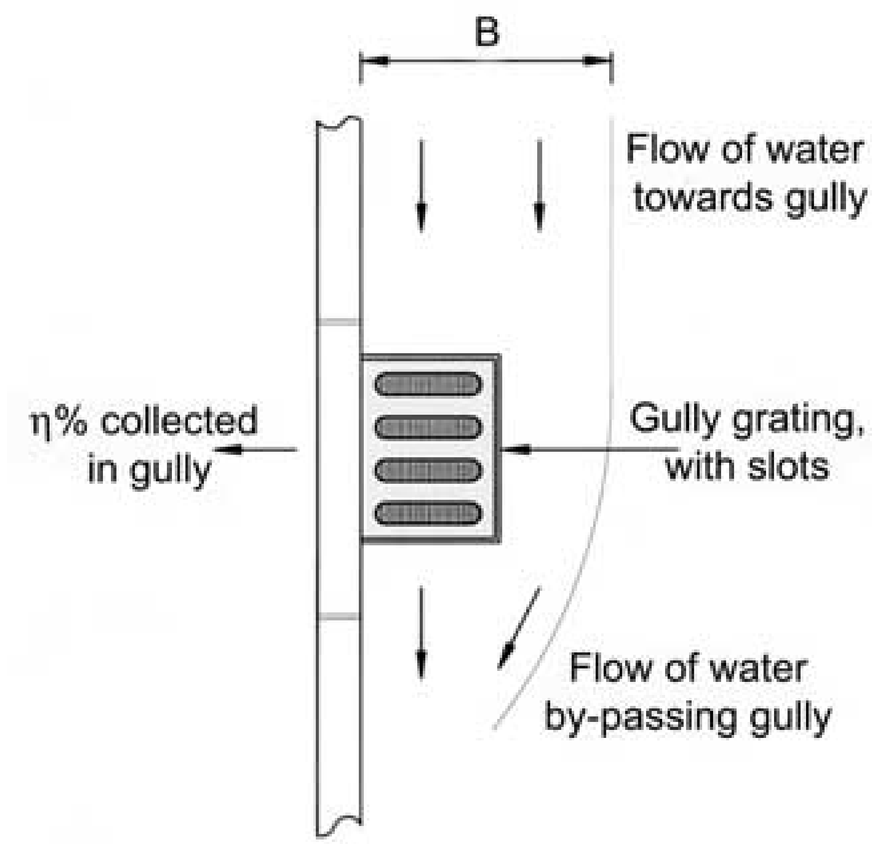

Figure 1b Flow of water along kerb and past grating

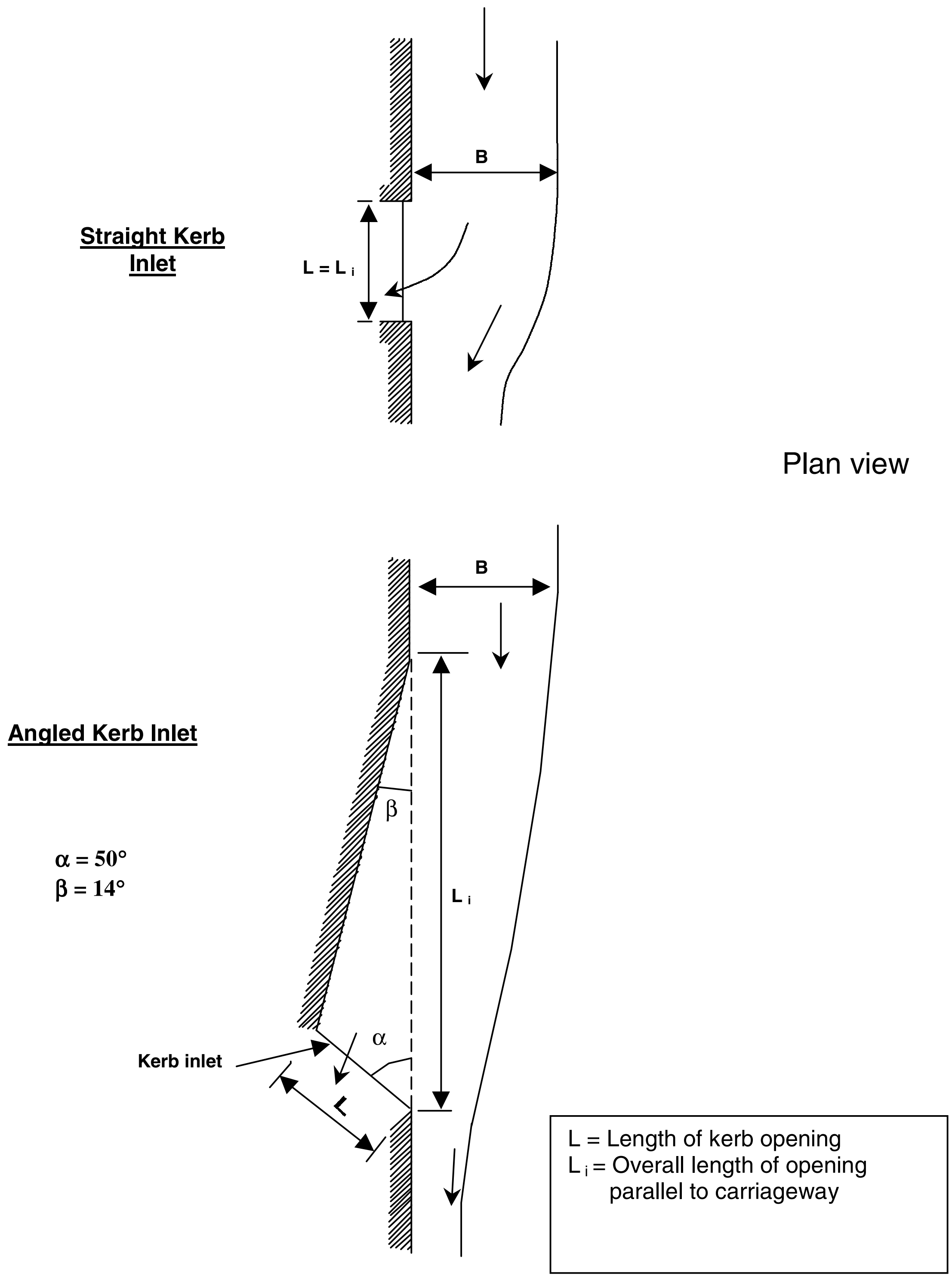

Figure 2 Layout of kerb inlets

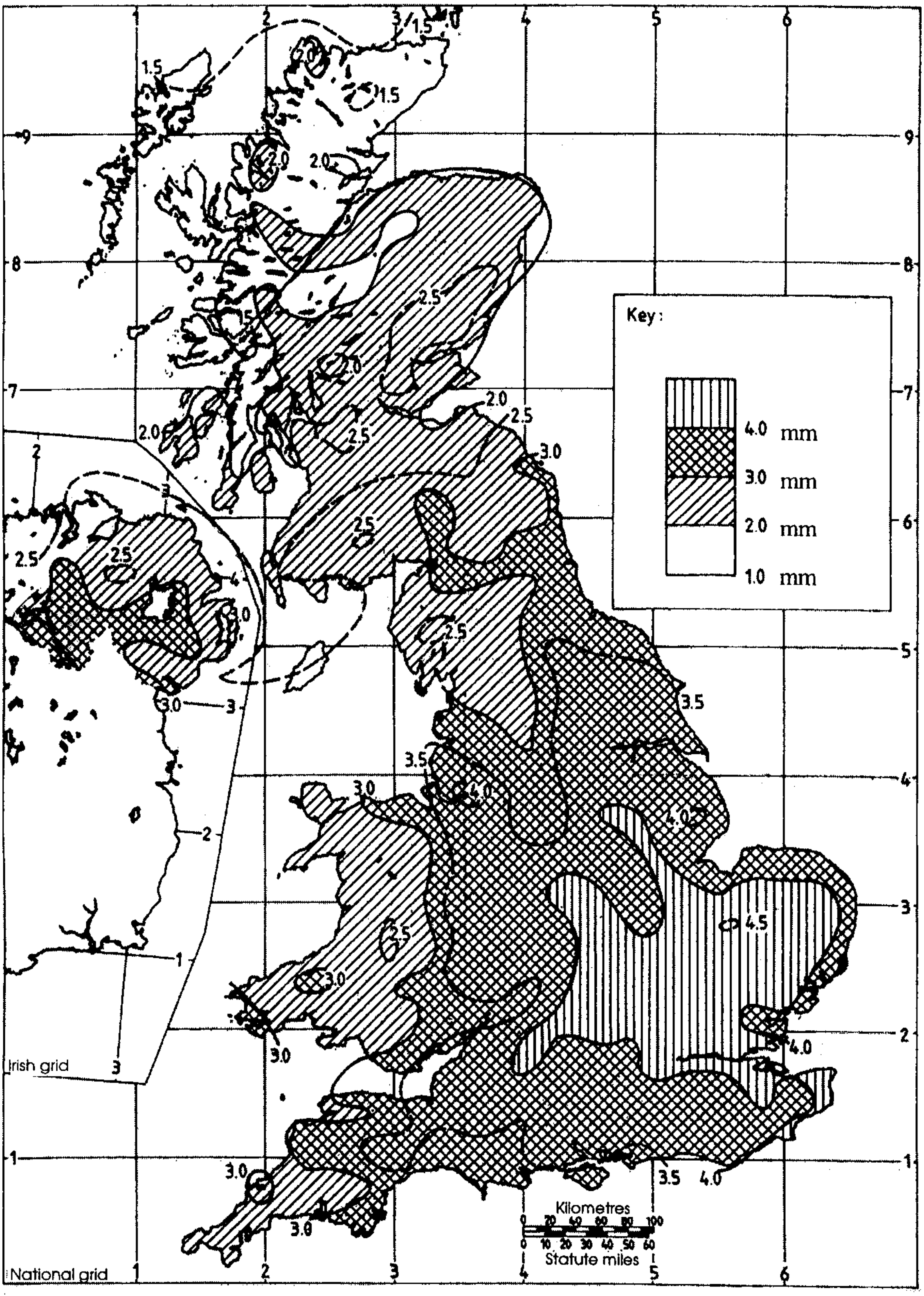

Figure 3 Values of 2minM5 rainfall depth for the UK
(Reproduced from BS6367:1983, as amended, by permission of the British Standards Institution)

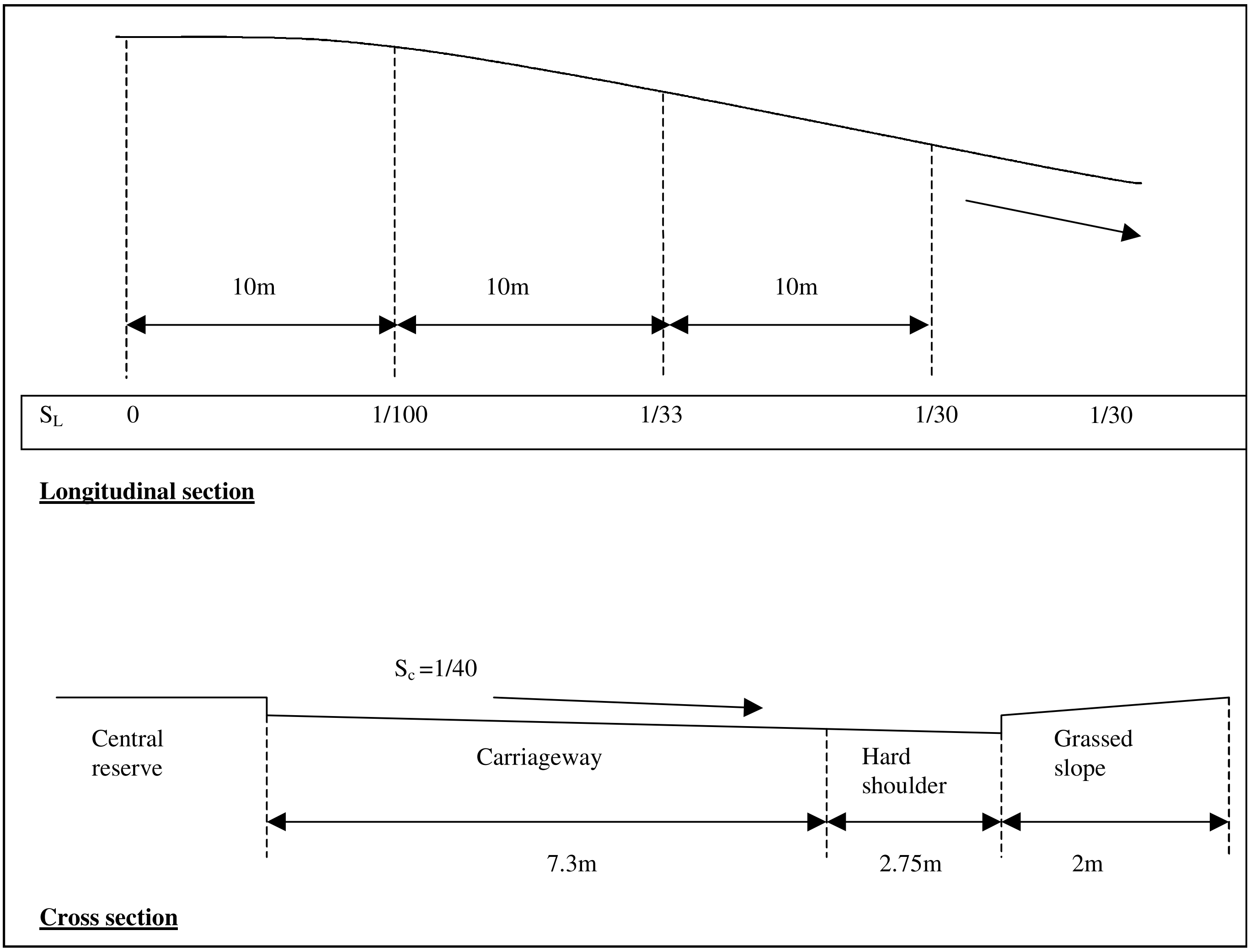

Figure 4a Urban motorway with non-uniform gradients

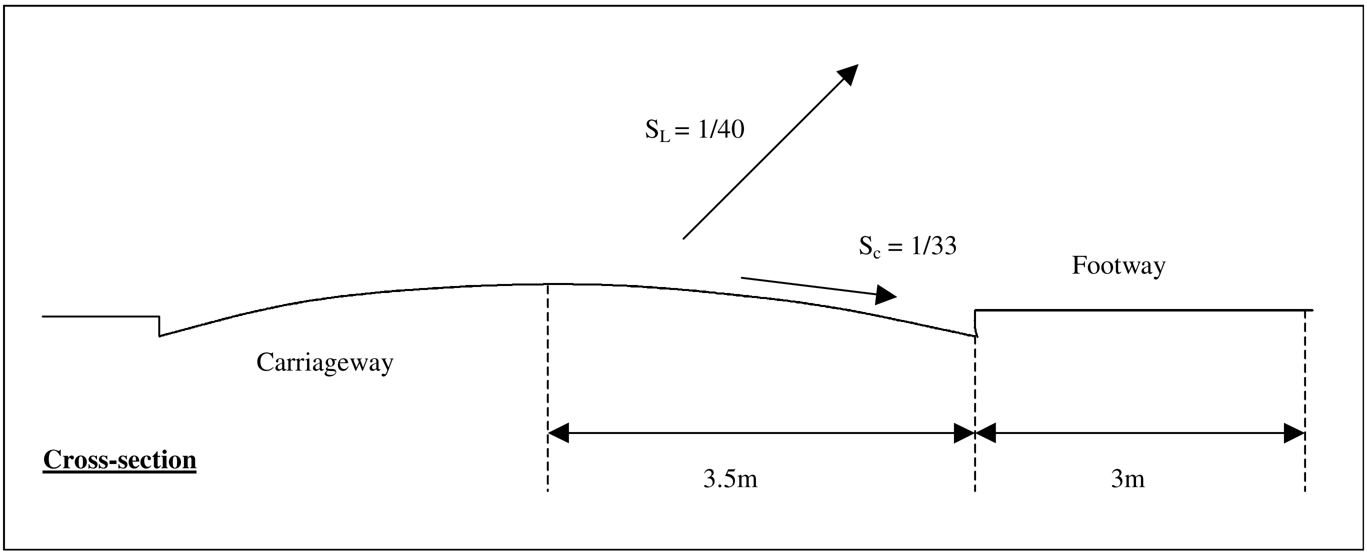

Figure 4b Urban single carriageway