SUMMARY

This Advice Note gives guidance on the hydraulic and structural design of grassed surface water channel for highway drainage. The type of system considered consists of a shallow surface water channel that is lined with grass.

INSTRUCTIONS FOR USE

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

3. Insert HA 119/06 into Volume 4, Section 2, Part 9.
4. Please archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.
Grassed Surface Water Channels for Highway Runoff

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May 2006
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May 2006
PART 9

HA 119/06

GRASSED SURFACE WATER CHANNELS FOR HIGHWAY RUNOFF

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1. INTRODUCTION

General
1.1 This Advice Note gives guidance on the hydraulic and structural design of grassed surface water channels for highway drainage. The type of system considered consists of a shallow surface water channel that is lined with grass. The grass sward reduces the flow velocity in the channel providing flow attenuation and facilitating deposition of suspended sediments and polluting heavy metals. Although, when compared with concrete surface water channels, the grassed channels will require more maintenance in the form of mowing, they do offer environmental benefits: a potential habitat for local fauna coupled with a better aesthetic value. The system is particularly suited to in-situ construction techniques. However, the hydraulic design procedures provided are generally applicable and are not limited to a particular method of construction. Although the advice should be fully taken into account in the design of new schemes (see 1.6), this Advice Note contains no mandatory requirements.

1.2 The function of the surface channel is to collect and convey rainwater runoff from the road surface. At suitable points along the channel, water is discharged into a separate carrier pipe to the rear, or possibly beneath the channel.

1.3 This Advice Note should be read in conjunction with the following documents in DMRB 4.2 (Ref 2):

• HD 33: Surface and Sub-Surface Drainage Systems for Highways;
• HA 37: Hydraulic Design of Road-Edge Surface Water Channels;
• HA 78: Design of Outfalls for Surface Water Channels;
• HA 83: Safety Aspects of Road Edge Drainage Features. Further details are given in TRL Report 422 (Ref 3);
• HA 103: Vegetated Drainage Systems for Highway Runoff.

1.4 The use of surface water channels should take account of advice on safety given in HA 83 (DMRB 4.2).

1.5 The selection of grassed surface water channels cannot be prescribed. Each situation must be considered individually taking into account the local landscape, geology, hydrology, climate and the practicality of provision for maintenance.

Scope
1.6 The principles outlined in this Advice Note apply to all schemes of Overseeing Organisations for trunk roads including motorways. They may also be applied generally to other new highway schemes and by other highway authorities for use during the preparation, design and construction of their own comparable schemes. Grassed surface water channel drainage systems may be installed during major maintenance works or as a retro-fit.

Implementation
1.7 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. In Northern Ireland, this Advice Note will be applicable to those roads designated by the Overseeing Organisation. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation (see HD 33 - DMRB 4.2).
2. SAFETY ASPECTS

General

2.1 When considering the use of a grassed surface water channel, safety aspects relating to its location should be taken into account in accordance with the guidelines given in HA 83, Safety Aspects of Road-edge Drainage Features (DMRB 4.2). Their use in the central reserve may not be appropriate if located at the pavement edge.

2.2 Grassed channels will usually be sited adjacent to the hardstrip or hardshoulder or at the edge of the carriageway and in front of the safety barrier, where one is provided. Layout details are given in the ‘A’ Series of the Highway Construction Details (HCD) (MCHW 3) (Ref 1). In these locations the maximum design depth of flow in the channel should be limited to 200 mm.

2.3 Grassed channels can be triangular or trapezoidal in cross-section. Non-symmetrical shapes can be considered provided account is taken of the following recommendations. In verges and central reserves, the side slopes of the channel should not be steeper than 1:5 (vertical : horizontal) for triangular and trapezoidal channels whether symmetrical or not. In very exceptional cases, the side slope remote from the running lane may have a slope of 1:4.5 if permitted by the Overseeing Organisation.

2.4 The need to minimise safety risks will inevitably mean that the layout of safety barriers and grassed channels should be agreed at an early stage in design and not left to compromise at later stages. Where safety barriers are not immediately deemed necessary, sufficient space should be provided in the verge or central reserve to allow for their possible installation. The combined layout must comply with the requirements of TD 19: Requirement for Road Restraint Systems (DMRB 2.2.8) and TD 27: Cross Sections and Headroom (DMRB 6.1.2).

2.5 The constraints on channel geometry given in this document also apply to the outlet arrangements used to discharge flow from the channel to the carrier drain or watercourse. For outlets and channel terminations, slopes exceeding 1:4 should not be used on any faces, particularly those orthogonal to the direction of traffic, unless such faces are behind a safety barrier.

2.6 Gully gratings used in a combined system to discharge water from the surface water channel to the adjacent carrier pipe (or to an outfall) should meet the geometrical and structural requirements of BS EN 124 (Ref 4) and BS 7903 (Ref 5) and be of the appropriate load class.

2.7 When dry, a grassed channel of appropriate construction, should be capable of supporting a heavy vehicle, refer to Plate D.4, without incurring significant damage. Where grassed channels are used in conjunction with All Purpose Roads, with a one metre hardstrip, and non accidental vehicle loading may be anticipated, for example a vehicle standing during routine maintenance operations, then consideration should be given to locally reinforcing the channel surface at these locations. (Refer to Chapters 11 and 12 and Plate D.3.)

Further advice on such layouts should be sought from the Overseeing Organisation.

2.4 The need to minimise safety risks will inevitably mean that the layout of safety barriers and grassed
3. DESCRIPTION

General

3.1 The drainage system described in this Advice Note consists of a grassed triangular or trapezoidal surface water channel that is installed at the pavement edge to collect and convey rainfall runoff from the road surface. The cross-sectional geometry of a typical grassed surface water channel system is shown in Figure C.1. Recommendations on appropriate methods of sub-surface drainage are given in Chapter 8.

Ground Water Implications

3.2 The Regulating Authority (RA) should be consulted whenever grassed surface water channels are proposed because infiltration of runoff through the channel can potentially impact on the receiving ground waters. Consultation would be part of the Environmental Assessment undertaken in accordance with the procedures in DMRB 11.3.10 (Ref 2).

3.3 The location of any aquifer should be determined, in particular the abstraction source and the protection afforded. There are three zones:

Source Protection Zone I (SPZ I) – Inner Source Protection: Immediately adjacent to the abstraction source and based on 50 day travel (flow) time from any point below the water table to the source (50 days is the decay period for biological contaminants).

Source Protection Zone II (SPZ II) – Outer Source Protection: This is defined as the 400 day travel time (to provide delay and attenuation of slowly decaying pollutants).

Source Protection Zone III (SPZ III) – Source Catchment: Is defined as the entire catchment for a groundwater source.

3.4 The use of grassed channels needs to be carefully considered in the vicinity of zones SPZ I and SPZ II, as protection measures will need to be agreed with the RA. Suitable measures may include the installation of an impermeable membrane beneath the channel. The membrane should be at a depth sufficient to retain moisture to maintain grass growth and to minimise the risk of damage should vehicles be driven over the channel. Note that the use of a cohesive subsoil in the channel construction is to be avoided due to poor performance when driven over.

Recommended Configuration

3.5 Grassed channels can be triangular (see Plate D.1) or trapezoidal in cross-section; non-symmetrical triangular channels can be considered to take advantage of the verge space (see Figure C.2). The configuration of the grassed channel should be of similar configuration to those of the concrete surface water channel, see HD 33 (DMRB 4.2) and HA 37 (DMRB 4.2) for guidance.

3.6 The width of the channel may be limited by the width of available verge. For safety reasons the depth should not exceed 200 mm or side slopes be steeper than 1:5 (vertical : horizontal) for triangular channels, or 1:4.5 (vertical : horizontal) for trapezoidal channels. In order to ensure effective conveyance, grassed channel depth should not be less than 150 mm.

3.7 Positioning grassed channels in the central reserve, especially at the pavement edge, may be inappropriate from both safety and routine maintenance aspects. Their use on high embankments is not recommended as percolation may destabilise the embankment slope.
4. ENVIRONMENTAL BENEFITS

General

4.1 Grassed surface water channels are a vegetated drainage system (see HA 103) (DMRB 4.2) and may also be considered to be a Sustainable Drainage System (SuDS), in that they use minimal non-replenishable materials such as quarried stone or oil based products. The system also offers potential environmental benefits not found in most conventional highway drainage techniques.

4.2 The visual environment is improved by the apparent reduction in width of the road, which for a rural Dual All Purpose carriageway could be between 10 and 15%. Replacing the concrete surface water channel by a grassed channel represents a visual ‘greening’ of the road.

Flow Attenuation

4.3 The increased surface roughness of the grassed channel in comparison with that of concrete will reduce the corresponding flow velocity. Comparison between average flow velocities in the two types of channel indicates velocities in grassed channels around 25% of those in concrete channels. A reduction in velocity will increase the time of flow within the channel and thereby increase the time of concentration. Consequently, the peak discharge flow rate to a receiving watercourse will be less from the grassed channel.

Sediment Deposition

4.4 The lower flow velocity generates less energy thereby reducing the sediment transport ability of the channel flow. Sediment will settle in the channel bed and be trapped by the grass blades.

Pollution Containment

4.5 Sediment is the prime constituent in the transport of heavy metals and polluting materials, such as lead, copper, zinc, cadmium etc. Metals are mainly contained in the suspended solids carried along by the channel flow and are removed when the solids are deposited as sediment. Increased sediment deposition will result in less of these pollutants reaching the receiving watercourse.

4.6 While grasses may not be as effective as reed beds in absorbing heavy metals and pollutants, the grass root system may remove some of the sediment borne contaminants. Table 7.1: Indicative Pollution Risk Reduction Factors for Drainage Systems of HA 216: Environmental Assessment Techniques: Road Drainage and the Water Environment (DMRB 11.3.10), ascribes the same risk reduction factor, 0.4, to grassed channels as to filter drains, soakaways/infiltration basins and sediment traps.

4.7 Under no, or low, flow conditions, accidental spillages may be readily contained due to the very low velocity of the spillage and the ability of the grass to retain the contaminant by permitting it to soak into the topsoil. The grass and contaminated soil may be removed and the channel section reconstructed.
5. HYDRAULIC DESIGN PRINCIPLES

General

5.1 The methods given in Chapter 6 for determining the drainage capacities of a grassed channel are based on the same principles as those used in HA 37 (DMRB 4.2) for conventional surface water channels. An outline description of the principles is given in this Advice Note.

5.2 It is a feature of the grassed channel that the longitudinal gradients of the channel normally be the same as the longitudinal gradient of the pavement being drained.

5.3 For a section of road at constant longitudinal gradient, the design should involve the following steps:

1. Assume a suitable size and cross-sectional geometry for the surface channel and use the method given in Chapter 6 to find the length of road, \( L \) (in m), that can be drained by the channel before it reaches its design capacity. This length, \( L \), determines the maximum allowable distance between the upstream end of the system and the first outlet and also the spacings between subsequent outlets to a carrier pipe line.

2. The carrier pipe should be designed to the principles set out in HD 33 (DMRB 4.2).

5.4 The hydraulic capacity of a grassed channel is a function of the following factors:

- The longitudinal gradient of the road, \( S \) (vertical fall per unit distance along the road, in m per m).
- The effective width, \( W_e \) (in m), of the catchment drained by the channel, taking account if appropriate of any run-off from cuttings (see Chapter 12 and Annex C of HA 37) (DMRB 4.2).
- The size, shape and cross-sectional area of the surface channel.
- The hydraulic roughness values of the channel, which are dependent on grass type and height, as well as on flow conditions.
- The statistical rainfall characteristics at the site, i.e. the relationship between the rainfall intensity, the duration of the design storm and its frequency of occurrence.
- The variation of rainfall intensity with time during the design storm.

5.5 The effects of these various factors can be taken into account using a method based on kinematic wave theory. This method provides information about the variation of flow conditions with time during a storm and enables the duration of storm that produces the worst flow conditions to be determined. The applicability of this method to the specific case of grassed channels where, in contrast with concrete channels, the hydraulic resistance of the grass depends on the flow conditions in the channel, was investigated and is described in Escarameia and Todd (Ref 6).

5.6 The flow capacity of the channel can be determined from the Manning resistance equation which has the form:

\[
Q = \frac{A R^{2/3} S^{1/2}}{n}
\]

where \( Q \) is the flow rate (in m³/s), \( A \) is the cross-sectional area of flow (in m²), and \( n \) is the Manning roughness coefficient of the channel. The hydraulic radius, \( R \) (in m), of the flow is given by:

\[
R = \frac{A}{P}
\]

where \( P \) is the wetted perimeter of the channel (in m).

5.7 The Manning’s roughness coefficient, \( n \), can be calculated using the following formulae derived from laboratory tests and validated using field trial data (Ref 6):

\[
n = 0.05 + 0.0048(1 + \alpha) \frac{H}{VR}
\]

with \( \alpha = 0 \) for Perennial Ryegrass dominated grass mixtures
\( \alpha = 1 \) for Fescues dominated grass mixtures
where H is the grass height in metres, V is the velocity in metres/second and R is the hydraulic radius in metres.

Equation (3) is applicable for VR>0.002. The great majority of design cases will be in that category; however, if any situations arise where VR<0.002, n can be calculated using the following expression:

\[ n = 0.05 + 2.4(1 + \alpha)H \] (4)

5.8 Rainfall statistics for short-duration storms in the UK can be approximated by the following equation:

\[ I_0 = 32.7 (N - 0.4)^{0.223} (T - 0.4)^{0.565} \frac{2\text{ min M5}}{T} \] (5)

where \( I_0 \) is the mean rainfall intensity (mm/h) occurring in a storm of duration T (minutes) with a return period of N (years), such that a storm of this intensity will occur on average once every N years. The quantity 2 min M5 is the depth of rainfall (in mm) occurring in a storm at the specified geographical location during a period of T = 2 minutes with a return period of N = 5 years. The variation of 2 min M5 with location in the UK is shown in Figure C.3. Details of the basis for Equation (5) are given in Annex A of HA 37 (DMRB 4.2).

5.9 The rainfall intensity in a storm is not usually constant but varies with time. The design equations given in Chapter 6 for the drainage capacities of channels assume that the intensity varies in accordance with what is termed the 50% summer profile, as defined in Volume 2 of the Flood Estimation Handbook (Ref 7). With this profile, the peak intensity at the mid-point of the storm is approximately 3.9 times the mean intensity, \( I_0 \), averaged over the total duration of the storm.

5.10 The higher resistance of grass, when compared with concrete and other artificial materials, generates lower flow velocities and flow rates in the channel (see Appendix B). For channels of equivalent size and slope, mean flow velocities in grassed channels can be of the order of 25% of those in concrete channels. Attenuation of peak flows is therefore better achieved in grassed channels and consequently the rate of discharge of runoff into the receiving watercourse is significantly slowed down.
6. DRAINAGE CAPACITY OF CHANNEL

Determination of Hydraulic Resistance

6.1 The first step in determining the capacity of grassed channels is concerned with the determination of the grass resistance coefficient. The procedure for obtaining this value is as follows:

- Define the cross-sectional characteristics of the channel. Assume design water depth is equal to 0.200 m.
- Determine the hydraulic radius, \( R \), of the channel as the ratio of the cross-sectional area and the wetted perimeter for the design water depth, see Equation (2). For the determination of these quantities, consider that the boundaries of the grassed channel are defined by the level of the soil from which the grass grows (as opposed to the tips of the grass blades).
- Decide on the grass mixture type (Fescues dominated mixture or Perennial Ryegrass dominated mixture) (see Chapter 10).
- For design purposes assume a grass height of \( H = 0.05 \) m for Fescues dominated mixture and \( H = 0.075 \) m for Perennial Ryegrass dominated mixture.
- Using the value of the longitudinal slope of the road, \( S \), calculate the term \( H/(R^{5/3}S^{1/2}) \), where \( H \) is the grass height (in metres) and \( R \) is the hydraulic radius (in metres) and calculate the following expression:

\[
2/13/51
\]

\[
SR \cdot mHn - = (6)
\]

where \( m = 0.0048 \) for Perennial Rye Grass and \( m = 0.0096 \) for Fescues dominated mix.

Values of \( n \) are typically within the range 0.05 to 0.1.
- Follow the procedure described in HA 37 (DMRB 4.2) to find the drainage length (see below).

6.2 Factors that influence the effective value of \( n \) are the grass stem density, grass stem length, soil composition, energy losses caused by the flow entering the channel from the road, and the presence of sediment or debris deposited in the channel.

Drainage Length

6.3 The surface channel is divided into separate drainage lengths by the intermediate outlets and terminal outfall. For a given size of channel, the maximum allowable distance between adjacent outlets will vary with the longitudinal gradient of the road and the effective width of the catchment being drained. The outlets may not, therefore, be equally spaced. Alternatively, it is possible to use a standardised spacing equal to the length of road that the channel can drain in the most critical section of the carrier pipe system.

6.4 For an individual section of surface channel, the drainage length, \( L \) (in m), is defined as the maximum length of road that can be drained by the channel under design conditions without the flow exceeding the allowable water depth in the channel. At the downstream end of the drainage length, the flow needs to be discharged from the channel to either the carrier pipe via an intermediate outlet, or to a watercourse or other drainage system via a terminal outfall (see Chapter 7).

6.5 In addition to the physical properties of the road and the channel, the value of \( L \) depends upon the rainfall characteristics at the site and the selected value of return period for the design storm. Based on the hydraulic principles described in Chapter 5, the following equation can be used to determine values of drainage length for triangular surface channels of symmetrical cross-section:

\[
L = 1.56 \times 10^6 \left( \frac{BY}{B^2 + 4Y^2} \right)^{2/3} \frac{S^{1/2}}{N} \left[ \frac{W_s (2 \text{ min} M5)}{n} \right]^{0.52} (7)
\]

where:

- \( Y \) is the design depth of flow in the triangular channel (in m) – see 2.2 and Figure C.1 or C.2;
- \( B \) is the corresponding surface width of flow (in m);
6.6 Equivalent formulae for the drainage capacities of other cross-sectional shapes of channel (asymmetric triangular, trapezoidal, rectangular and dished) are given in Chapter 5 of HA 37 (DMRB 4.2).

6.7 The maximum flow capacity, $Q$ (in m$^3$/s), of a surface channel when it is just flowing full at its design depth of flow, $Y$, can be determined from the Manning resistance Equation (1). For the particular case of a triangular channel of symmetrical cross-section, the equation has the form:

$$Q = 0.315 \frac{(B Y)^{1/3}}{(B^2 + 4Y^2)^{1/2}} \frac{S^{1/2}}{n}$$

(8)

6.8 If the longitudinal gradient of the road and the surface channel varies along the drainage distance, $L$, the value of $S$ in Equations (7) and (8) should be replaced by the effective value of longitudinal gradient, $S_e$. This can be estimated approximately from:

$$S_e = \frac{\Delta Z}{L}$$

(9)

where $\Delta Z$ (in m) is the difference in invert level of the channel between the upstream and downstream ends of the drainage length, $L$. If the variation in longitudinal gradient is considerable, a more accurate estimate of $S_e$ may be obtained from Equation (15) in HA 37 (DMRB 4.2), Chapter 7. In either case, an iterative procedure may be necessary to determine $S_e$ if the longitudinal profile of the road has been determined in advance of the hydraulic design.

6.9 Table B.1 of Appendix B provides a comparison of flow capacities of concrete and grassed channels over a range of longitudinal gradients.

Storm Return Period

6.10 Recommendations on the selection of design storm return periods for highway drainage systems are given in Chapter 6 of HD 33 (DMRB 4.2). Surface channels should be designed so that flows produced by storms with return periods of $N = 1$ year are contained within the cross-section of the channel (i.e. the design depth, $Y$, in Equation (7) is not exceeded).

Surcharging of the Channel

6.11 Limited surcharging of surface channels is permissible during rarer storms. In verges, the maximum width of flow on the road surface during storms with return periods of $N = 5$ years should not exceed 1.5 m in the case of hard shoulders and 1.0 m in the case of hard strips. For central reserves, checks will be necessary to avoid water flow encroaching on to the carriageway due to storms of return periods of $N = 5$ years.

6.12 The following simplified method may be used to calculate the length of road that a surface channel can drain to an outlet when the channel is flowing in a surcharged condition:

- First use Equation (7) to calculate the maximum length of road, $L$ (in m), that can be drained by the channel when just flowing full at the design flow depth, $Y$, for storms having a return period of $N = 1$ year.
- The maximum length of road, $L_s$ (in m), that the channel can drain to an outlet in the surcharged condition for storms having a return period of $N = 5$ years is given by:

$$L_s = \phi L$$

(10)

where $\phi$ is a factor given in Table 6.1 and is dependent on the allowable width of flow, $B_s$, on the adjacent hard strip or hardshoulder.
Table 6.1 – Values of $\phi$

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<td>Allowable width on hard strip $B_s = 1m$</td>
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<td>1:30</td>
<td>1.5</td>
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<tr>
<td>1:40</td>
<td>1.4</td>
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<td>1:50</td>
<td>1.2</td>
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This simplified method assumes that the channel has a symmetrical triangular profile and provides estimates of $L_S$ that will tend to err on the conservative side.

6.13 The maximum flow capacity of the channel, $Q_S$ (in m$^3$/s), under surcharged conditions can be estimated from:

$$Q_S = 1.575 \phi Q$$  \hspace{1cm} (11)

where the value of $Q$ is the design capacity of the channel obtained from Equation (8).

**Flow By-passing at Intermediate Outlets**

6.14 Because velocities in grassed channels are so low in comparison with concrete, it is expected that, even under surcharged conditions, the volume of flow by-passing the gratings would be minimal, therefore outlet gratings are designed on 100% efficiency.
7. OUTLETS AND TERMINAL OUTFALLS

General

7.1 The outlet from the channel should be of similar arrangement to that of concrete channels, described in HA 78 (DMRB 4.2). The grating may be either flat or V-shaped to correspond with the channel profile. To avoid dangers to vehicles or flooding, care should be taken to ensure the level of the grating is not higher than the invert level at the centre of the channel.

7.2 The growth of grass around the outlet may obstruct flow into the grating. To minimise the risk of this occurring, the immediate area around the grating should be paved to form an apron. (See also 7.5 below.) The surround (apron) to the grating acts as a transition from the grassed channel; and may be formed using concrete or plastic cellular block grass reinforcement, hence incorrect positioning of the apron will be expensive to rectify.

7.3 The terminal outlet may contain more than one grating, which may necessitate extending the apron beyond the downstream end of the channel. Refer to Figure C.5B and to the terminal outlet detail in HA 78 (DMRB 4.2).

7.4 The piped sub-surface drainage system, e.g. Type 6 fin drain, may be connected to intermediate chambers but should be connected to the terminal outlet chamber. Ensure that the level of the outlet from the chamber is below this sub-surface pipe so that surcharge will not result in a back flow of water into the sub-surface drain.

7.5 The outlets from the channel form a solid obstruction within an area of comparatively soft channel construction. Any vehicle wheel that impacts with the outlet structure could be damaged or, if travelling at a high velocity, the vehicle itself may be damaged. To minimise this risk it is recommended that a transition zone in the form of an apron, is constructed around the outlet structure. This apron should be of a cellular structure, comprising concrete or plastic blocks incorporating holes for topsoil and grass growth, inclined to slope downwards from the edge of the outlet to below the channel, see detail in Figure C.4. This should absorb much of the energy and protect both the vehicle and the structure.

Intermediate Outlets

7.6 Intermediate outlets for grassed channels, see Figures C.4 and C.5A, consist of gratings, installed in the base of the channel, that discharge the flow from the surface water channel to a carrier pipeline or, in certain circumstances, directly to a watercourse.

7.7 The hydraulic design of the gratings (type, spacing, number) is described in HA 78 (DMRB 4.2). The following alternative geometries for intermediate outlets, presented in HA 78 (DMRB 4.2), are generally suitable for grassed channels:

(1) **In-line outlet**, the preferred option, where the water is essentially collected symmetrically through the channel invert (see Figures B5, B7 and B9 of HA 78, DMRB 4.2); or

(2) **Off-line outlet**, where the channel is widened away from the carriageway and the outlet is offset from the centreline of the channel (see Figures B6, B8 and B10 of HA 78, DMRB 4.2).

For triangular channels the in-line design is generally more efficient than the off-line design, but reasons for choosing between them will mainly depend on constructional aspects (see Chapter 11). Other factors being equal, in-line outlets are preferable to off-line outlets because they can enable use of a narrower verge.

Terminal Outfalls

7.8 Terminal outfalls comprise chambers with catchpits that also receive flow from the grassed channel and convey the flow to a suitable watercourse, ditch or continuation carrier pipe.

7.9 To avoid a vehicle losing control when a channel is not protected by a safety barrier, the upper surface of the terminal outfall should terminate with a smooth transition, without abrupt changes in level or width (following the recommendations in 3.16 of HA 78, DMRB 4.2).

7.10 The plan shape of the chamber will be determined by the layout of the gratings forming the terminal outfall. The invert level of the outgoing pipe from the chamber should be governed by the following two criterias:
(1) The invert level should be set at a minimum of 300 mm above the bottom of the chamber to provide an adequate volume for sediment retention.

(2) The invert level should be such that the water level in the chamber does not rise high enough to prevent flow discharging freely from the surface channel into the chamber.

7.11 In order to meet criterion (2) in 7.10, it is recommended that the water level in the chamber should be at least 150 mm below the underside of the gratings when the chamber is receiving flow from the channel under surcharged conditions. The height $Z$ (in m) of the water surface in the chamber above the invert of the outgoing pipe can be estimated from the equation:

$$ Z = \frac{D}{2} + 0.23 \frac{Q^2}{D^4} $$

(12)

where $D$ is the diameter of the outgoing pipe (in m) and $Q$ is the design flow rate (in m$^3$/s).

7.12 The gradient and diameter of the outgoing pipe from the chamber should be determined from a suitable resistance equation or flow tables (such as HR Wallingford and Barr, (Ref 8)) assuming that the pipe is just running full at the design flow rate, $Q$.

7.13 An example of a suitable layout for a terminal outfall chamber is given in Figures C.4 and C.5B.

Steep Roads

7.14 On steep roads (typically with gradients of $S > 1/50$), the flow collection efficiency of the gratings may be insufficient due to the effect of high water velocities in the surface channel. There is currently insufficient knowledge of grassed channel performance at steep gradients. It is, therefore, recommended that alternative drainage systems are used in this situation.
8. **SUB-SURFACE DRAINAGE**

### General

8.1 The sub-surface water flow occurring due to water percolating through the bed of the channel must be prevented from entering the unbound pavement foundation, where the presence of moisture can cause premature failure of the pavement.

### Drainage System

8.2 A sub-surface drainage system should be provided to ensure that any percolation through the channel is intercepted before reaching the unbound pavement layers; a typical detail is shown in Figure C.1.

8.3 A suitable system is the installation of a fin drain, Type 5 or 6 in Detail F18 of the HCD, (MCHW 3), at the edge of the pavement construction. The fin drain should incorporate a double cuspated central core, made from a suitable impermeable material such as polyethylene or polypropylene, which acts as a barrier between the two constructions.

8.4 The top of the fin drain should be located above the top of the pavement sub-base level, but care is necessary to ensure that the fin does not protrude into the grassed topsoil.

8.5 Where an impermeable liner is installed beneath the top soil layer, the liner should extend over the sub-surface drainage.
9. SOIL PROPERTIES

General

9.1 The channel should comprise of graded subsoil, a layer of topsoil and sub-surface drainage (see Chapter 8). The subsoil should be graded to the required cross-sectional and longitudinal profiles.

9.2 The channel may be either seeded or lined with turf. Where seeded directly on to the topsoil, the depth of topsoil should be minimal, around 35mm, to ensure that the grass roots penetrate the subsoil and bond the two layers together.

9.3 A geo-grid may be placed between the two soil layers to provide reinforcement until the grass becomes established. The use of a biodegradable material is preferable and should provide protection for some 2 to 3 years. The geo-grid is usually held in place by U-shaped steel pins or staples. The presence of the staples should be borne in mind when considering the use of grassed channels, especially where an impermeable liner is required (see 3.4).

Subsoil Requirements

9.4 Advice on suitable soils and their placement is given in HA 56, The Good Roads Guide: New Roads Planting, Vegetation and Soils (DMRB 10.1.2) (Ref 2). The formation on which the subsoil is spread should be roughened to a depth of 150mm to provide a key between the two materials.

9.5 The subsoil should be non cohesive and fairly permeable, having permeability in the order of $10^{-4}$ m/s, after compaction, to ensure that the grass roots get air as well as water.

9.6 The subsoil should be free from stones larger than 50mm and, where a membrane is used, free from flints.

Topsoil Requirements

9.7 The topsoil used should comply with BS 3882 Specification for topsoil (Ref 11), general purpose topsoil, screened for stones larger than 50mm.

9.8 To ensure good grass growth it is recommended that, in terms of textural classification, the soil should be a sandy loam or loamy sand, with a pH greater than 5.5.

9.9 The ideal depth of topsoil is around 35mm but should not exceed 50mm as greater depths of topsoil will encourage the growth of weeds and other forms of vegetation.

Topsoil Preparation

9.10 The steps for seedbed/turfbed preparation are as follows:

- cultivation of the topsoil and rolling, under suitable ground conditions to form the seedbed;
- application of lime, dependent on pH test results. Acid soils, for example, the pH range is from 6.0 to 6.5;
- application of seedbed fertiliser e.g. 10:15:10 (N:P$_2$O$_5$:K$_2$O) at 30 g/m$^2$;
- final raking or harrowing before seeding/hydroseeding or turfing.
10. GRASS TYPE SELECTION

Suitable Grass Types

10.1 No standard verge mix is specified in Clause 3005 of the SHW (MCHW 1).

10.2 When selecting the most appropriate grass types for surface water channels the main issues to be considered are:

- suitability of grasses for different climatic areas;
- ease of establishment;
- salt tolerance;
- susceptibility to pollution from exhaust emissions and runoff from road surfaces;
- tolerance of the wetter conditions that may prevail in drainage channels;
- growth rates;
- erosion control;
- recovery rates from damage.

Regional Variation in Climate

10.3 A wide range of cool season grasses is potentially available within grassed drainage channels in the UK. The climatic range is probably not great enough to justify differences in seed mixtures for different parts of the country, but grasses that predominate after establishment will be influenced by both climate and soil type.

Grass Establishment

10.4 The advantages and disadvantages of various techniques for establishing grass within the channel (seeding, hydro-seeding and turfing) are set out in Table 10.1.

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeding</td>
<td>Control over grass seed used.</td>
<td>Potential loss of seed if heavy rainfall occurs during establishment. Greater risk of erosion.</td>
</tr>
<tr>
<td></td>
<td>Low cost.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seed will generally remain dormant if there are hot dry spells after sowing but will establish when suitable weather conditions return.</td>
<td></td>
</tr>
<tr>
<td>Hydroseeding</td>
<td>Control over grass seed used.</td>
<td>More expensive than conventional seeding.</td>
</tr>
<tr>
<td></td>
<td>Less risk of seed loss if heavy rain occurs during establishment.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Less risk of erosion.</td>
<td></td>
</tr>
<tr>
<td>Turfing</td>
<td>Instant grass cover.</td>
<td>High initial cost.</td>
</tr>
<tr>
<td></td>
<td>Less risk of erosion.</td>
<td>High labour requirement/cost for laying.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cost of mowing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vulnerable to drying out if hot, dry spell occurs after laying.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unless specifically grown for grassed drainage channels, may not have the grass species required.</td>
</tr>
</tbody>
</table>

Table 10.1 – Advantages and Disadvantages of Different Establishment Methods
10.5 If grassed channels are to be established from seed, it is important that the seed germinates quickly and that the grass cover develops rapidly. Roadside verges are unlikely to receive irrigation to help establishment therefore the requirement is for grass types that will develop quickly.

10.6 The speed of grass establishment varies according to the species. The establishment rates for common UK turf grasses (Ref 9) are shown in Table 10.2 below.

<table>
<thead>
<tr>
<th>Species</th>
<th>Speed of Establishment (5=best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial ryegrass</td>
<td>5</td>
</tr>
<tr>
<td>Timothy</td>
<td>4</td>
</tr>
<tr>
<td>Crested dogstail</td>
<td>4</td>
</tr>
<tr>
<td>Strong creeping red fescue</td>
<td>4</td>
</tr>
<tr>
<td>Rough stalked meadow grass</td>
<td>4</td>
</tr>
<tr>
<td>Slender creeping red fescue cv</td>
<td>3-4</td>
</tr>
<tr>
<td>Dawson</td>
<td></td>
</tr>
<tr>
<td>Tall fescue</td>
<td></td>
</tr>
<tr>
<td>Perennial ryegrass</td>
<td></td>
</tr>
<tr>
<td>Chewings fescue</td>
<td>3</td>
</tr>
<tr>
<td>Annual meadow grass</td>
<td>3</td>
</tr>
<tr>
<td>Sheeps’ hard fescue</td>
<td>2</td>
</tr>
<tr>
<td>Bents</td>
<td>2</td>
</tr>
<tr>
<td>Smooth stalked meadow grass</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 10.2 – Establishment Rates for Common Turf Grasses

10.7 The use of salt for de-icing requires the consideration of salt tolerance. Table 10.3 below gives an indication of salt tolerance of the main turf grasses. None of the grasses has a high salt tolerance, in contrast to some warm-season species, but the most tolerant are slender creeping fescue, tall fescue and perennial ryegrass (Ref 10).

<table>
<thead>
<tr>
<th>Salt Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately Tolerant</td>
</tr>
<tr>
<td>Slender creeping red fescue cv</td>
</tr>
<tr>
<td>Dawson</td>
</tr>
<tr>
<td>Tall fescue</td>
</tr>
<tr>
<td>Perennial ryegrass</td>
</tr>
<tr>
<td>Moderately Susceptible</td>
</tr>
<tr>
<td>Annual meadow grass</td>
</tr>
<tr>
<td>Chewings fescue</td>
</tr>
<tr>
<td>Creeping bent</td>
</tr>
<tr>
<td>Strong creeping red fescue</td>
</tr>
<tr>
<td>Hard fescue</td>
</tr>
<tr>
<td>Rough stalked meadow grass</td>
</tr>
<tr>
<td>Susceptible</td>
</tr>
<tr>
<td>Annual meadow grass</td>
</tr>
<tr>
<td>Browntop bent</td>
</tr>
<tr>
<td>Smooth stalked meadow grass</td>
</tr>
</tbody>
</table>

Table 10.3 – Salt Tolerance of Turf Grasses

10.8 Grass is more resistant to phytotoxic effects of lead and other heavy metals than most other plants although very high concentrations can affect growth.

10.9 Some species such as strong creeping red fescue are known to have a greater resistance to heavy metals.

10.10 Raising the soil pH by liming improves plant health but has a detrimental effect on the plants absorption of toxic micronutrients and heavy metals.

10.11 Grassed channels will probably be wetter than grass verges on comparable soil types. This may cause changes in the balance of grass species over time, favouring grasses such as timothy, perennial ryegrass and annual meadow grass that are more tolerant of wet conditions. It is quite probable that these grasses may eventually become more dominant in the lower lying central section of the grassed channel, whereas the drier upper slope may retain grasses better adapted to the drier conditions, such as fescues.
**Growth Rate**

10.12 Road side verges are low maintenance areas and consequently it is desirable that any grasses used are slow growing so that mowing frequency is minimised and the volume of cuttings reduced.

<table>
<thead>
<tr>
<th>Species</th>
<th>Low Growth Rate (5=lowest rate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial ryegrass</td>
<td>1-2</td>
</tr>
<tr>
<td>Strong creeping red fescue</td>
<td>1-2</td>
</tr>
<tr>
<td>Timothy</td>
<td>1-2</td>
</tr>
<tr>
<td>Slender creeping red fescue</td>
<td>2-3</td>
</tr>
<tr>
<td>Smooth stalked meadow grass</td>
<td>2-4</td>
</tr>
<tr>
<td>Crested dogstail</td>
<td>3</td>
</tr>
<tr>
<td>Chewings fescue</td>
<td>3</td>
</tr>
<tr>
<td>Sheep’s hard fescue</td>
<td>3</td>
</tr>
<tr>
<td>Rough stalked meadow grass</td>
<td>3</td>
</tr>
<tr>
<td>Bents</td>
<td>3-4</td>
</tr>
<tr>
<td>Annual meadow grass</td>
<td>3-5</td>
</tr>
</tbody>
</table>

*Table 10.4 – Growth Rates for Turf Grasses*

10.13 Growth rates will be modified by fertility and soil moisture content, guidance on growth rates (Ref 9) is shown in Table 10.4.

**Damage Recovery**

10.14 The most likely cause of physical damage to the grassed channel is from vehicle over-run. The amount of damage that occurs will be dependent on the weight of the vehicle and the interaction between the soil moisture content and soil strength.

10.15 In severe cases extra topsoil and re-levelling may be required to repair deeper ruts.

10.16 The inclusion of a biodegradable matting should assist in the reinforcement of the grassed channel as the sward becomes established.

10.17 Recovery rates for different grasses (Ref 9) are given in Table 10.5.

<table>
<thead>
<tr>
<th>Species</th>
<th>Recuperation (5=best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perennial ryegrass</td>
<td>5</td>
</tr>
<tr>
<td>Annual meadow grass</td>
<td>5</td>
</tr>
<tr>
<td>Timothy</td>
<td>3-4</td>
</tr>
<tr>
<td>Smooth stalked meadow grass</td>
<td>3-4</td>
</tr>
<tr>
<td>Slender creeping red fescue</td>
<td>3</td>
</tr>
<tr>
<td>Chewings fescue</td>
<td>3</td>
</tr>
<tr>
<td>Strong creeping red fescue</td>
<td>2-3</td>
</tr>
<tr>
<td>Bents</td>
<td>2-3</td>
</tr>
<tr>
<td>Sheep’s hard fescue</td>
<td>2</td>
</tr>
<tr>
<td>Crested dogstail</td>
<td>1</td>
</tr>
<tr>
<td>Rough stalked meadow grass</td>
<td>1</td>
</tr>
</tbody>
</table>

*Table 10.5 – Recovery Rates for Turf Grasses*

**Indicative Grass Seed Mix**

10.18 Both Perennial Ryegrass dominated mixtures and Fescues dominated mixtures are particularly suitable for grassed channels. The following is an example of a resilient and slow growing mix, but is by no means the only mix suitable:

- 20% Perennial Ryegrass
- 10% Highland Bent
- 20% Chewings Fescue
- 40% Slender Creeping Red Fescue
- 10% Smooth stalked Meadow Grass

May 2006
11. CONSTRUCTION ASPECTS

Verge Ancillaries

11.1 A large number of ancillary structures can be positioned adjacent to the carriageway and will require accommodation within, or close to, the grassed channel and to which access will be required. These structures can include fixed sign and variable message sign structures, gantries, lighting and CCTV columns, motorway communications cabinets and roadside emergency telephones.

Ducted cables

11.2 Ducts for motorway communications cables are located in the verge. The location for the ducts is shown on drawings HCD MCX 0810 (MCHW 3a).

11.3 Ducts run both parallel to and perpendicular to the carriageway and require the construction of chambers at changes in direction. It is essential that chambers are remote from the grassed channel as ducts are a means of introducing surface water into the pavement construction. It is also essential that the grassed channels do not run off surface water on to the chamber tops allowing the introduction of surface water into the duct network. The arrangement of chambers and motorway communications cabinets are shown on drawings HCD MCX 0812 (MCHW 3a). The depth of ducts is shown on drawings HCD MCX 0814 (MCHW 3a).

Directly Buried Cables

11.4 Trenches in the verge for directly buried motorway communications cables are shown on drawing HCD MCX 0140 (MCHW 3a).

Detector Loops

11.5 Detector loops in the carriageway surface and loop joint chambers in the verge result in very shallow cables being present at the carriageway edge. The designer should be aware of the potential conflict between these cables and the grassed channel. Detector loops are generally installed at 500m intervals. HD20 (DMRB 9.3) and HCD G9 (MCHW 3) provide information.

Signage

11.6 Signs are generally remote from the pavement edge and are protected by safety barriers. The designer should ensure that no signs encroach into the channel. Marker posts may encroach into the grassed channel and care should be taken to ensure that their installation will not result in any impermeable membrane being punctured.

Lighting Columns

11.7 Lighting columns should be remote from the pavement edge, however where lighting columns are proposed, the designer should ensure that any waterproof membrane used is brought around the structure and that the columns themselves are protected from channel flows.

Safety Barriers

11.8 Barriers may encroach into the grassed channel and any impermeable membrane should be positioned around the posts, refer also to Chapter 2.

11.9 The presence of barriers may adversely affect the maintenance (mowing) of the grass and hence the suitability of grassed channels where long sections of barriers are proposed.

Grassed Channel Construction

11.10 It is recommended that a fin drain is installed at the edge of pavement to intercept infiltration through the grassed channel before it reaches the pavement construction (see Chapter 8) and similarly intercept flows from beneath the pavement. The recommended fin drain is either a Type 5 or Type 6 (see F18 and F19 of the HCD - MCHW 3) with a double cusped core.

11.11 During construction of the channels, temporary measures may be necessary to prevent surface runoff from the pavement, or verge, washing away the topsoil or surcharging the fin drain.

11.12 To reduce the risk of topsoil becoming saturated due to heavy rain, subsoil (where imported) and topsoil placement should commence at the highest point of the channel and work downstream.
11.13 The subsoil should be well compacted, if possible in layers approximately 100mm thick and up to 50mm of topsoil spread and compacted on top. An allowance should be made for the thickness of turf, if used, when defining the final level of the topsoil. Note that subsoil and topsoil, when placed in landscaped areas are not normally compacted, however, in order to minimise the risk of damage caused by vehicles running into the channel, the soils should be compacted in this instance.

11.14 Where turf is used, this should be placed immediately after compaction of the topsoil to minimise the risk of soil fines being washed away by surface runoff. Turfing offers advantages over hydro-seeding in that it will give a much greater level of initial protection to the topsoil and hydro-seeding is very dependent on the quality of the seed mixture and the fibre reinforcement.

11.15 The grassed channel should be operational at the end of the road construction stage. To avoid long establishment times in Winter months as well as the inclement weather of the hotter and colder months, grassed channel construction should preferably be undertaken in early Spring or early Autumn.

Use in Combination with a French Drain

11.16 The typical filter (French) drain will be between 600mm and 1000mm wide and located against the pavement edge. Where it is proposed to remediate a problem such as stone scatter, by applying a topsoiled surfacing, it may be practical to incorporate a grassed channel in the surfacing. A detail for a grass surface to filter drains is shown in B15 and in F2 Type L and Type M of the HCD (MCHW3).

11.17 To be viable, there needs to be an additional width of verge behind the French drain that can be included in the construction of the grassed channel.

11.18 As a surfacing to existing filter (French) drains, sufficient stone filter medium and depth of adjacent verge material should be removed to permit the formation of the 200mm channel and sufficient depth of topsoil. A geotextile may be positioned over the filter material to prevent topsoil (and sub-soil) from contaminating the drain, but still permitting water to soak through.

11.19 The properties of the geotextile should comprise:

- Porosity – should not be impermeable but should have permeability no greater than the compacted subsoils (channel needs to retain moisture to be able to support the grass).
- Woven or non-woven – material must be durable and be clog resistant (not proof since the aim is to maintain channel flow on the surface).
- Tensile strength – must have adequate tear and puncture resistance to permit compaction of the channel subsoil and topsoil above it and be resistant to vehicle over run damage.

11.20 The topsoil (and subsoil) should be very well compacted.

Vehicle Pull Off Location

11.21 Access to communications apparatus and similar equipment may necessitate vehicles being deliberately driven on to the grassed channel, particularly where there is only a one metre hardstrip. In these circumstances it may be appropriate to locally reinforce the grassed channel to minimise damage should the channel surface be softened by water flowing in the channel. Appropriate grass reinforcement systems include installing a reinforcing mat within the topsoil and grass roots, (see Plate D.3), or proprietary grass surface reinforcement products.

Field Access

11.22 Where grassed channels are proposed for use on All Purpose Roads, the presence of field access crossings should be considered. In these instances, the grassed channel should terminate at the crossing and recommence on the downstream side. A terminal outfall chamber and carrier drain will be required. The ends of the grassed channel should be sufficiently remote from the crossing that there is no risk of over-running by farm vehicles as they turn.
12. MAINTENANCE

Frequency of Grass Cutting

12.1 Ideally, for optimum hydraulic performance, the grass blades should be no longer than 75mm. The mowing regime should be developed accordingly. It is anticipated that the grass should be mown three times during the late spring and summer.

12.2 The grassed channel profile should be capable of being mowed using the same equipment that is used to maintain the verge.

Weed Control

12.3 Invasion of the grassed channel by weeds and native grass species is inevitable since mowing alone will not prevent this. Low broad leaved weeds will cause the local grass to die back, however due to the relatively short drainage path to the watercourse, the use of herbicides should be carefully considered.

Removal of Litter and Detritus

12.4 The presence of litter and debris will cause the underlying grass to die with the consequential result of bare patches that may become prone to erosion. The use of grassed channels may not be appropriate on sections of road subject to very high traffic densities and the consequent frequent periods of slow moving and stationary traffic.

Repair of Vehicular Damage

12.5 Vehicle over-run can result in rutting of the grass surface, especially if the channel is wet, or recently constructed.

12.6 While damp, ridges in the grass sward can be readily tamped down; wheel ruts may necessitate lifting the turf and placing an additional fine tilth of topsoil before recompacting the turf.

Patching

12.7 Where the grass has died or is severely damaged, the affected area should be removed, the topsoil level reinstated and a section of appropriate turf inserted. The replacement turf should be watered regularly until it becomes established in the channel.

Grassed Surface Reinforcement

12.8 Where a grass reinforcement system has been incorporated into the grassed channel construction, these areas should be identified within the drainage data management system (HD 43 - DMRB 4.2) and, especially during immediate post construction grass cutting operations where a reinforcement mat has been installed, care should be taken to ensure mechanical grass cutting does not result in damage to the mat.
13. WORKED EXAMPLE

13.1 It is necessary to determine the spacing between the intermediate outlets and the terminal outfall for a grassed surface water channel that will drain a section of dual two-lane carriageway near Norwich. The pavement is black top with a cross fall of 1:40 on non-superelevated sections. The width of the carriageway is 9.3m (including two 1.0m wide hardstrips. The longitudinal gradient of the road is 1 in 125, S=0.8%, and is at grade so will not receive runoff from the adjacent pervious area.

13.2 The principal features of the system are as follows:

- **Surface water channel:**
  - Symmetrical triangular channel with crossfalls of 1:5 (vertical : horizontal).
  - Design flow depth: \( Y = 0.2m \).
  - Corresponding flow width: \( B = 2.00m \).

- **Roughness coefficient \( n \):**
  - Grass type: Perennial Ryegrass.
  - Average grass height: \( H = 0.075m \) for PRG.

- **Overall cross-sectional shape:**
  - The grassed surface water channel is to be designed to allow a maximum width of surcharging of 1.0m on the adjacent hardstrip. For a straight section of road, with a crossfall of 1:40, this can be achieved by setting the outer edge of the channel 25mm above the level at the edge of the hardstrip. There is to be an upstand at the edge of the channel, nominally equal to 40mm. Given that the sides of the channel have crossfalls of 1:5, it follows that the overall width of the channel will be equal to \( B + (0.065 \times 5) = 2.325m \). (applies only to the side of the channel remote from the carriageway).

13.3 Determine the roughness coefficient (Manning’s \( n \)) using Equation (6).

- Assuming Perennial Ryegrass mix (PRG), then \( m=0.0048 \) and \( H \) assumed at 0.075m.
- Flow width \( B = 2.0m \), Depth \( Y = 0.2m \), Slope \( S=0.008 \) (1 in 125m).
- Substitute in Equation (6) and \( n = 0.062 \).

13.4 The effective catchment width, \( W_E \), draining to the grassed surface water channel is equal to the width of the carriageway plus the width of the grassed channel, including the additional width due to surcharge.

\[
W_E = 9.30 + 2.325 = 11.625m
\]

13.5 The characteristic rainfall depth for the Norwich area is found from the map in Figure C.3.

2min M5 = 4.0mm

13.6 The first step in the hydraulic design is to determine the required spacing between intermediate outlets along the grassed channel. Flows produced by storms with a return period of \( N = 1 \) years must be contained within the surface water channel with the flow depth not exceeding \( Y = 0.20m \). Substituting the values in Equation (7), it is found that the maximum drainage length is:

\[
L = 411m
\]

13.7 The maximum length of road, \( L_s \) (m) that the channel can drain to an outlet in the surcharged condition for storms of return period \( N=5 \) years, is determined from Equation (10) where the value \( \Phi \) can be obtained from Table 6.1:

\[
\Phi = 1.4 \quad L_S = 575m
\]

13.8 The maximum flow capacity, \( Q \) (in m\(^3\)/s), of the grassed channel when just flowing full at design depth of flow, \( Y = 0.2m \), can be determined from Equation (8).

\[
Q = 0.061m^3/s
\]

13.9 The maximum flow capacity of the channel, \( Q_s \) (in m\(^3\)/s), under surcharged conditions can be estimated from Equation (11), where the value of \( \Phi \) can be obtained from Table 6.1:
where $\Phi = 1.4$, $Q_s = 0.135 \text{m}^3/\text{s}$

13.10 The maximum depth of water in the outlet chamber should not rise to within 150mm of the underside of the grating under design flow conditions, see 7.11. Assume outgoing pipe diameter = 300mm and insert in Equation (12).

$$Q = 0.061 \text{m}^3/\text{s} \quad Z = 256 \text{mm}$$

There is no surcharge at design flow, so 300mm diameter is adequate.

Under surcharged flow conditions, $Q_s$

$$Q_s = 0.135 \text{m}^3/\text{s} \quad Z = 668 \text{mm}$$

Therefore, the outgoing pipe invert must be at least 0.818m (i.e. 0.668 + 0.150) below underside of grating.
14. REFERENCES AND BIBLIOGRAPHY

   Specification for Highway Works (SHW) (MCHW 1).


   Highway Construction Details (HCD) (MCHW 3).

2. Design Manual for Roads and Bridges (DMRB) (The Stationery Office)
   HD 33 – Surface and Sub-surface Drainage Systems for Highways (DMRB 4.2).

   HA 37 – Hydraulic Design of Road-Edge Surface Water Channels (DMRB 4.2).

   HA 39 – Edge of Pavement Details (DMRB 4.2).

   HD 43 – Drainage Data Management System for Highways (DMRB 4.2).


   HA 78 – Design of Outfalls for Surface Water Channels (DMRB 4.2).

   HA 83 – Safety Aspects of Road-edge Drainage Features (DMRB 4.2).

   HA 103 – Vegetated Drainage Systems for Highway Run-off (DMRB 4.2).

   TD 19 – Requirement for Road Restraint Systems (DMRB 2.2.8).

   TD 27 – Cross Sections and Headroom (DMRB 6.1.2).

   HA 216 – Environmental Assessment Techniques: Road Drainage and the Water Environment (DMRB 11.3.10).

   HD 20 – Detector Loops for Motorways (DMRB 9.3)


15. ENQUIRIES

All technical enquiries or comments on this Advice Note should be sent in writing as appropriate to:

<table>
<thead>
<tr>
<th>Divisional Director</th>
<th>A J PICKETT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Safety &amp; Information)</td>
<td>Divisional Director</td>
</tr>
<tr>
<td>Highways Agency</td>
<td></td>
</tr>
<tr>
<td>Room 4B, Federated House</td>
<td></td>
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<tr>
<td>London Road</td>
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<tr>
<td>Dorking</td>
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<td>Surrey RH4 1SZ</td>
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<table>
<thead>
<tr>
<th>Chief Road Engineer</th>
<th>J HOWISON</th>
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<tbody>
<tr>
<td>Transport Scotland</td>
<td>Chief Road Engineer</td>
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<td>Edinburgh</td>
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<tr>
<th>Chief Highway Engineer</th>
<th>M J A PARKER</th>
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<td>Transport Wales</td>
<td>Chief Highway Engineer</td>
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<tr>
<td>Welsh Assembly Government</td>
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<tr>
<td>Cathays Parks</td>
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<tr>
<td>Cardiff</td>
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<tr>
<td>CF10 3NQ</td>
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<table>
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<tr>
<th>Director of Engineering</th>
<th>G W ALLISTER</th>
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<tr>
<td>The Department for Regional Development</td>
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</tr>
<tr>
<td>Roads Service Headquarters</td>
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</tr>
<tr>
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</tr>
<tr>
<td>10-18 Adelaide Street</td>
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</tr>
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### APPENDIX A  LIST OF SYMBOLS

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<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Units</th>
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<tbody>
<tr>
<td>$A$</td>
<td>Cross-sectional area of flow in channel</td>
<td>m$^2$</td>
</tr>
<tr>
<td>$B$</td>
<td>Surface width of flow in channel</td>
<td>m</td>
</tr>
<tr>
<td>$B_s$</td>
<td>Allowable width of flow on hard strip or hardshoulder adjacent to channel during surcharged conditions</td>
<td>m</td>
</tr>
<tr>
<td>$D$</td>
<td>Diameter</td>
<td>m</td>
</tr>
<tr>
<td>$H$</td>
<td>Grass height</td>
<td>m</td>
</tr>
<tr>
<td>$I_o$</td>
<td>Mean rainfall intensity</td>
<td>mm/h</td>
</tr>
<tr>
<td>$L$</td>
<td>Drainage length of channel, i.e. maximum length of road that can be drained by a section of surface channel at design depth of flow</td>
<td>m</td>
</tr>
<tr>
<td>$L_s$</td>
<td>Maximum length of road that can be drained by a section of surface channel under surcharged conditions</td>
<td>m</td>
</tr>
<tr>
<td>$N$</td>
<td>Return period of storm</td>
<td>years</td>
</tr>
<tr>
<td>$n$</td>
<td>Manning roughness coefficient of channel</td>
<td>-</td>
</tr>
<tr>
<td>$P$</td>
<td>Wetted perimeter of channel</td>
<td>m</td>
</tr>
<tr>
<td>$Q$</td>
<td>Flow rate in channel</td>
<td>m$^3$/s</td>
</tr>
<tr>
<td>$Q_s$</td>
<td>Flow capacity of channel in surcharged condition</td>
<td>m$^3$/s</td>
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<tr>
<td>$R$</td>
<td>Hydraulic radius of flow ($=A/P$)</td>
<td>m</td>
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<tr>
<td>$S$</td>
<td>Longitudinal gradient of road or channel (vertical fall per unit distance along road or channel)</td>
<td>m/m</td>
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<td>$S_e$</td>
<td>Effective value of $S$ for road or channel of non-uniform gradient</td>
<td>m/m</td>
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<tr>
<td>$T$</td>
<td>Duration of storm</td>
<td>minutes</td>
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<tr>
<td>$V$</td>
<td>Velocity of flow</td>
<td>m/s</td>
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<tr>
<td>$W_e$</td>
<td>Effective width of catchment drained by surface channel</td>
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<tr>
<td>$Y$</td>
<td>Design depth of flow in surface channel (from invert)</td>
<td>m</td>
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<tr>
<td>$Z$</td>
<td>Height of water surface in outfall chamber above invert level of outgoing pipe</td>
<td>m</td>
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<tr>
<td>$\Delta Z$</td>
<td>Difference in invert level of channel between upstream and downstream ends of drainage length</td>
<td>m</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Surcharge factor (ratio between drainage length for surcharged channel and drainage length for channel just flowing full)</td>
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<tr>
<td>$2\text{min}M5$</td>
<td>Rainfall depth occurring in 2 minutes with return period of 5 years</td>
<td>mm</td>
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# APPENDIX B  TABLES

<table>
<thead>
<tr>
<th>Channel</th>
<th>Concrete channel</th>
<th>Perennial Rye Grass 40mm</th>
<th>Fescues 40mm</th>
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<tbody>
<tr>
<td>Side slopes</td>
<td>Longitudinal Slope</td>
<td>Flow Depth m</td>
<td>R (m)</td>
</tr>
<tr>
<td>1 in 5</td>
<td>0.067</td>
<td>0.10</td>
<td>0.050</td>
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Table B.1 – Comparison of Flow Capacities of Concrete and Grassed Channels Over a Range of Longitudinal Gradients
APPENDIX C FIGURES

Figure C.1: Typical triangular grassed channel cross-section
Figure C.2: Schematic channel profiles
Figure C.3: Values of $2\text{minM}_5$ rainfall depth for UK
Figure C.4 Typical outlet detail
Figure C.5: Typical outlet detail (plan)
Figure C.1 – Typical Triangular Grassed Surface Water Channel
Figure C.2 – Schematic Channel Profiles

A. Symmetrical Triangular

B. Asymmetrical Triangular

C. Symmetrical Trapezoidal

D. Asymmetrical Trapezoidal

Max 40mm Upstand (Min. 30mm)
Figure C.3 – Values of $2\text{minM}_5$ Rainfall Depth for UK
(Reproduced from BS 6367:1983 by permission of British Standards Institution)
Figure C.4 – Typical Outlet Detail
Figure C.5 – Typical Outlet Detail (plan)
APPENDIX D  PLATES

Plate D.1: General View of Grassed Channel

Plate D.2: Outlet Arrangement Showing Cellular Blockwork
Plate D.3: Reinforcing Mat Showing Securing Pin (NB mat should be below topsoil)

Plate D.4: Vehicle Loaded to 38 Tonnes Used in Full Scale Trial