VOLUME 4 GEOTECHNICS AND DRAINAGE
SECTION 2 DRAINAGE

PART 3

HD 33/06

SURFACE AND SUB-SURFACE DRAINAGE SYSTEMS FOR HIGHWAYS

SUMMARY

This Standard gives guidance on the selection of the types of surface and sub-surface drainage for trunk roads including motorways. It describes the various alternative solutions that are available to drain trunk roads in the UK, including their potential to control pollution and flooding. It also includes guidance on drainage of earthworks associated with highway schemes and appropriate signing for pollution control devices.

INSTRUCTIONS FOR USE

This revised Advice Note is to be incorporated in the Manual.

1. This document supersedes HD 33/96 which is now withdrawn.
2. Remove existing Contents pages for Volume 4, and insert new Contents pages for Volume 4 dated May 2006.
3. Remove HD 33/96, which is superseded by HD 33/06 and archive as appropriate.
4. Insert HD 33/06 into Volume 4, Section 2, Part 3.
5. Please archive this sheet as appropriate.

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THE HIGHWAYS AGENCY

TRANSPORT SCOTLAND

WELSH ASSEMBLY GOVERNMENT
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THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Surface and Sub-Surface Drainage Systems for Highways

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Volume 4 home page

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Contents

1. INTRODUCTION

General

1.1 This Standard gives guidance on the selection of the types of surface and sub-surface drainage for trunk roads including motorways. It describes the various alternative solutions that are available to drain trunk roads in the UK, including their potential to control pollution and flooding. It also includes guidance on drainage of earthworks associated with highway schemes and appropriate signing for pollution control devices

Scope

1.2 The guidance given on drainage design is applicable to all trunk road projects. It provides a summary of design documents available, primarily those published on behalf of the Overseeing Organisations. It describes the various alternative solutions that are available to drain trunk roads in the UK, including their potential to control pollution and flooding. It advises upon selection in principle, and gives advice on the detailed design of the various pavement edge drainage alternatives with regard to available design guides.

Implementation

1.3 This Standard 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.

Design Principles

1.4 There are three major objectives in the drainage of trunk roads:

i) the speedy removal of surface water to provide safety and minimum nuisance;

ii) provision of effective sub-surface drainage to maximise longevity of the pavement and its associated earthworks; and

iii) minimisation of the impact of the runoff on the receiving environment.

It is also necessary to provide for drainage of earthworks and structures associated with the highway.

1.5 The performance of pavement foundations, earthworks and structures can be adversely affected by the presence of water, and good drainage is therefore an important factor in ensuring that the required level of service and value for money are obtained. Highway drainage can be broadly classified into two elements -surface and sub-surface drainage, but these two aspects are not completely disparate. Surface water is able to infiltrate into road foundations, earthworks or structures through any surface which is not completely impermeable, and will thence require removal by sub-surface drainage unless other conditions render this unnecessary.

1.6 The necessary objectives can be achieved by:

i) combined systems, where both surface water and sub-surface water are collected in the same pipe; or

ii) separate systems, where the sub-surface water is collected in a separate drainage conduit from the one which is used for collection of surface water. Sub-surface water of a separate system will be collected in a fin or narrow filter drain.

Each system has certain advantages and disadvantages and one may be more appropriate than the other in any particular situation.

1.7 Drainage networks incorporating systems such as oil separators, sediment traps, filter drains, wetlands and other vegetated systems can, by virtue of their design, provide a degree of control over pollution and flood control. The three main processes applicable to the treatment of highway runoff are:

- sedimentation – the removal of suspended solids;
- separation – the removal of all solids and non-aqueous liquids;

- vegetated treatment processes, including filtration, settlement, adsorption, biodegradation and plant uptake, depending on the type and combination of systems.

The selection and design of systems will depend on the pollution load, the risk of spillage or flood and the site conditions, particularly if protected species or sites may be affected. In practice, the network is likely to be a combination of systems. Guidance on the assessment of the risk of either pollution or flooding is given in HA 216 Road Drainage and the Water Environment (DMRB 11.3.10). Chapter 7 of this Standard gives examples of conventional drainage systems that have the potential to mitigate the effects of runoff. Guidance on vegetated drainage systems is given in HA 103 Vegetated Drainage Systems for Highway Runoff (DMRB 4.2). Guidance on the design of soakaways is given in HA 118 Design of Soakaways (DMRB 4.2) and on the design of grassed surface water channels in HA 119 Grassed Surface Water Channels for Highway Runoff (DMRB 4.2).

Volume 4 home page

2. EFFECT OF ROAD GEOMETRY ON DRAINAGE

Introduction

2.1 Road surfacing materials are traditionally designed to be effectively impermeable, and only a small amount of rainwater should percolate into the pavement layers. It is important that any such water is able to drain through underlying pavement layers and away from the formation. Rainfall which does not permeate the pavement surface must be shed towards the edges of the pavement.

Road Geometry

2.2 Drainage is a basic consideration in the establishment of road geometry and vertical alignments should ensure that:

a) outfall levels are achievable; and

b) subgrade drainage can discharge above the design flood level of any outfall watercourses.

These considerations may influence the minimum height of embankments above watercourses. They could also influence the depth of cuttings as it is essential that sag curves located in cuttings do not result in low spots which cannot be drained.

TD 9 (DMRB 6.1.1) and TD 16 (DMRB 6.2.3) contain guidance to minimise problems and dangers in shedding water from carriageways. The following paragraphs summarise good practice advocated in these documents with regard to the interaction of geometry and drainage and therefore the minimum standards of road geometry which the drainage designer would generally expect.

2.3 TD 9 (DMRB 6.1.1) indicates that consideration of drainage of the carriageway surface is particularly important in areas of flat longitudinal gradient and at rollovers. Where longitudinal gradients are flat it is better to avoid rollovers completely by adoption of relatively straight alignments with balanced crossfalls.

Drainage can then be effected over the edge of the carriageway to channels, combined surface water and ground water drains or some other form of linear drainage collector. Gullies may be required at very close spacings on flat gradients.

Areas of superelevation change require careful consideration. Where superelevation is applied or removed the crossfall on the carriageway may be insufficient for drainage purposes without assistance from the longitudinal gradient of the road. TD 9 (DMRB 6.1.1) suggests that a longitudinal gradient of 0.5% should be regarded as the minimum in these cases. This is the nett longitudinal gradient including the effects of the application of superelevation acting against the gradient where superelevation is:

a) applied on a downhill gradient; or

b) removed on an uphill gradient.

To achieve a resultant gradient of 0.5% may require a design line gradient of 1.5%. Alternatively the superelevation area may be moved to a different location by revision of the horizontal alignment, or in extreme cases a rolling crown may be applied. It is essential that a coordinated analysis of the horizontal and vertical alignments with reference to surface water drainage is carried out before alignments are fixed. It should also be borne in mind that permissible standards adopted in design may not be achieved in practice as a consequence of the construction tolerances permissible for road levels. TA 80 (DMRB 4.2) gives further guidance.

2.4 TD 16 (DMRB 6.2.3) provides guidance on crossfall and longitudinal gradients for carriageway drainage of roundabouts. Roundabouts are designed with limited crossfall to provide smooth transitions and reduce the risk of loads being shed from vehicles turning through relatively small horizontal radii. Consequently areas of carriageways may become inherently flat. Careful consideration should be given to road profiling and the net gradients which result from combination of crossfall and longfall. These may be best indicated by contoured drawings of the required carriageway surface.

Safety Considerations

2.5 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 important. Detailed advice is given in HA 83 (DMRB 4.2).

2.6 Whilst the behaviour of an errant vehicle and its occupants is unpredictable and deemed to be hazardous, the Designer must consider carefully the safety implications of the design and minimise potential hazards as far as possible.

The Designer must also give appropriate consideration to the safety of motorcyclists and non-motorised road users.

Channel Flow Widths

2.7 The width of channel flow against a kerb face will generally increase in the direction of longitudinal gradient until the flow is intercepted by a road gully, grating or other form of collector.

Design guidance on determination of spacing of road gullies is given in HA 102 (DMRB 4.2): 'Spacing of road gullies'.

2.8 A basic criterion in all these studies is the width of channel flow adjacent to a kerb which is deemed to be permissible. This is a site-specific consideration which should be evaluated against such factors as highway standard, carriageway width, speed limit, lighting, proximity of footway or cycleway, and contiguous width of hard strip or hard shoulder. Guidance on design storms is summarised in paragraph 6.2.

2.9 Similar considerations of flow width apply to the design of surface water channels under surcharged conditions, and are defined in HA 37 (DMRB 4.2).

Surface water channels are formed as an extension to the basic pavement width of a highway, and comprise a dished section within which the selected design storm will be accommodated. Storms of greater intensity will surcharge the channel and can be accommodated by permitting a width of flow to encroach onto the adjacent hard shoulder or hard strip. Differences in safety considerations consequential to flooding adjacent to the offside lane of a superelevated section of dual carriageway, rather than adjacent to a nearside lane, are recognised and dealt with in HA 39 (DMRB 4.2).

Surface Drainage of Wide Carriageways and at Merges and Diverges

2.10 Guidance is given in TA 80 (DMRB 4.2) on the design of drainage for wide carriageways and for junction areas and changes of superelevation. Where a slip road or main carriageway crossfalls towards the nose of a merge or diverge section of an interchange or junction, it will be necessary to provide drainage within the nosing.

Such drainage should intercept all runoff which would accumulate in the nosing or flow across the nosing onto an adjacent pavement. This can be effected by a longitudinal grated or slotted linear drainage channel, or by road gullies within a suitably dished cross-section of the nosing.

It is essential that such drainage installations must be safe and structurally adequate to allow for not just errant vehicles but also usage which may occur during motorway lane closures and the trafficking of hard shoulders. Particular care must be taken in respect of abnormal load routes.

3. SURFACE WATER COLLECTION: EDGE DRAINAGE DETAILS

Introduction

3.1 Surface water runoff from the edges of UK roads is generally collected by kerbs and gullies, combined kerb and drainage blocks, surface water channels and channel blocks, linear drainage channels or by direct runoff into combined surface water and ground water filter drains adjacent to the pavement edge.

3.2 MCHW and DMRB deal in some detail with kerbs and gullies, surface water channels, both concrete and grassed, channel blocks, combined channel and pipe systems, and combined surface water and ground water drains. Guidance upon their application is set out in TA 57 (DMRB 6.3), HA 37 (DMRB 4.2) , HA 39 (DMRB 4.2), HA 102 (DMRB 4.2), HA 113 (DMRB 4.2) and HA 119 (DMRB 4.2). Usage of combined kerb and drainage blocks requires that design requirements be set out by the designer in numbered Appendices 1/11 and 5/5 to the Specification (MCHW 2). This can be best achieved by consideration of available proprietary precast units. The completed appendices should permit usage from as wide a range as possible of acceptable alternatives.

Linear drainage channels comprise closed conduits into which water drains through slots or gratings in the tops. Combined channel and pipe systems comprise surface water channels having an internal pipe formed within the base of the units that is able to carry additional flow.

3.3 Each of these alternative modes of drainage is dealt with in more detail later in this Standard. General applications of their usage are shown in Table 3.1 and a list of documents giving further guidance is set out in Table 3.2. Recommended design selections from the various alternatives for verge and central reserve situations respectively are illustrated diagrammatically in Figures 3.1 and 3.2.

The location and design of outfalls for highway drainage are important considerations. Advice on the design of outfalls and culverts is given in HA 107 (DMRB 4.2), and guidance on soakaway design can be found in HA 118 (DMRB 4.2). Considerations of detention storage and specific pollution control measures may influence selection of drainage solutions and are described later in this Standard. Advice on vegetated drainage systems is given in HA 103 (DMRB 4.2).

Kerbs and Gullies

3.4 Road surface drainage by kerbs and gullies is commonly used in the UK, particularly in urban and embankment conditions. ‘Gullies and Pipe Junctions’ requirements are set out in MCHW 1. Gully connection pipes discharge to outfall generally via longitudinal carrier pipes set within the verge. The function of kerbs is not purely to constrain edge drainage. They provide some structural support during pavement laying operations and protect footpaths and verges from vehicular overrun.

3.5 An indirect hazard to vehicles can be presented by edge details that permit adjacent build-up of widths of water flow, which may intrude into the hard shoulder, hard strip or carriageway of the highway. This can occur with edge details that do not immediately remove water linearly from the adjacent pavement in all storm situations. The edge detail to which this problem is most pertinent is the raised kerb detail commonly used on urban roads. Functioning of kerb and gully systems is dependent upon the build up of a flow of water in front of the kerb. Gully spacings will be set out to suit an acceptable width of flow for the design storm as set out in paragraphs 2.7 and 2.8.

3.6 One advantage of kerbs and gullies is that a longitudinal gradient to carry road surface runoff to outfall is not dependent upon the longitudinal gradient of the road itself, and can be formed within a longitudinal carrier pipe. MCHW 3 illustrates permissible alternative types of gully that provide for varying degrees of entrapment of detritus.

3.7 Road gullies will generally discharge to associated longitudinal carrier drains except on low embankments with toe ditches where it may prove more economical to discharge gullies direct to the toe ditches via discrete outfalls. Fin or narrow filter drains would drain the pavement layers and formation in such instances.

3.8 Cuttings with high ground water flows (HA 39, DMRB 4.2) will require conventional deep filter drains instead of fin or narrow filter drains. It is often difficult to provide a filter drain and a separate carrier drain to collect gully connections within a normal verge width.

In such circumstances there is justification for the adoption of combined surface water and ground water filter drains. Where gullies are required connections should be made directly into junction pipes in accordance with MCHW 1. Pipe types permitted for the carrier drains must be able to accommodate this requirement.

Surface Water Channels

3.9 Surface water channels are normally of triangular concrete section, usually slip-formed, set at the edge of the hard strip or hard shoulder and flush with the road surface. They are illustrated in MCHW 3 and referenced in MCHW 1. They are the preferred edge-detail solution on trunk roads and motorways, and their usage is described in HA 39 (DMRB 4.2).

3.10 Significant benefits can include ease of maintenance and the fact that long lengths, devoid of interruptions, can be constructed quickly and fairly inexpensively. It may be possible to locate channel outlets at appreciable spacings and possibly coincident with watercourses. However carriageways with flat longitudinal gradients may necessitate discharge of channels fairly frequently into outfalls or parallel longitudinal carrier pipes in order to minimise the size of the channels. It will probably be found most economic to design surface water channels such that outlet spacings in the verges are coincident with cross-carriageway discharges from the central reserve.

3.11 It is reasonable to assume that the relative risk to vehicles and occupants from impingement on surface water channels is lower than would be expected from impingement on other drainage features such as kerbs, embankments and ditches, as the channels present a much lower risk of vehicles losing contact with the ground or overturning.

Drainage Channel Blocks

3.12 These are smaller in section than surface water channels. They are illustrated in MCHW 3 and are referenced in MCHW 1. Guidance on their use is also set out in HA 39 (DMRB 4.2). They are not permitted as edge drains contiguous with hard shoulders, hard strips or carriageways in order to collect direct runoff from those elements of the highway.

3.13 There are potential maintenance difficulties associated with the use of drainage channel blocks and the designers will need to give consideration to these factors:

i) any settlement of adjacent unpaved surfaces would reduce their effectiveness;

ii) they may be prone to rapid build up of silt and debris in flat areas; and

iii) grass cutting operations by mechanical plant will be jeopardised adjacent to the channel.

Some roads are drained by 'grips' which comprise shallow channels excavated across verges to allow drainage from road edges to roadside ditches. These suffer many of the same disbenefits. Grips and channel blocks should be avoided in verges subject to frequent usage by equestrians or other vulnerable users.

Combined Kerb and Drainage Blocks

3.14 Combined kerb and drainage blocks are precast concrete units either in one piece or comprising separate top and bottom sections. A continuous closed internal channel section is formed when contiguous blocks are laid. The part of a unit projecting above road level looks like a wide kerb unit and contains a preformed hole that admits water into the internal cavity. Units are typically 400-500mm long and the preformed holes thus occur at that spacing. They are illustrated in MCHW 3 B16 and are referenced in MCHW 1.

3.15 They are especially useful where kerbs are necessary at locations of little or no longitudinal gradient, particularly at roundabouts where their linear drainage function removes the need for any 'false' crowning of road-edge channels. They can be useful where there are a number of public utility services, especially in urban areas. They may be economic in rock cuttings, if the high cost of carrier drain installation in such situations can be thereby avoided.

Linear Drainage Channels

3.16 These are included in MCHW 1 and can be manufactured or formed in situ. Manufactured units may be of concrete, polymer concrete, glass reinforced concrete or other material. They are in all cases set flush with the carriageway and contain a drainage conduit beneath the surface into which surface water enters through slots or gratings. They can also be of in situ concrete. Manufactured units have been commercially available for many years, but in situ construction has been adopted much more recently in the UK. When used on shallow gradients they may be prone to maintenance difficulties as described in paragraph 3.13. Advice may be sought from the Overseeing Organisation on current experience in maintaining these systems.

Combined Channel and Pipe Systems

3.17 These are similar to surface water channels, with the addition of a pipe formed within the system. This provides extra flow capacity for a channel of the same width, reducing the number of outfalls from the system and reducing, or even eliminating the need for a separate carrier pipe. Where space is limited (for example, in road widening schemes) they allow a narrower channel to be built than would otherwise be possible.

This system is described in HA 113 (DMRB 4.2) and may be used wherever surface water channels would be suitable. Like surface water channels, they are particularly suited to in situ construction in concrete using slip forming techniques. Where they are used in situations that require sub-surface drainage of the pavement, the sub-surface drain will be located between the pavement construction and the channel, as the latter will form a barrier to the horizontal movement of moisture at the pavement edge. This is different from usual practice for solid surface water channels.

Over-the-edge Drainage

3.18 This method of drainage, applicable to embankment conditions, is illustrated in MCHW 3 B13, and its usage is described in HA 39 (DMRB 4.2). It is inappropriate for usage in locations where footways or segregated cycleways abut carriageways, on structures or on embankments constructed on moisture susceptible soils. Uncontrolled growth on verges can inhibit free drainage.

Grassed Surface Water Channels for Highway Runoff

3.19 Grassed channels are a development of swales for use as road edge channels. They have gentle slopes and are often combined with over-the-edge drainage or combined surface water and ground water filter drains. They are becoming increasingly common due to their potential to control both storm water runoff rates and pollution. HA 119 (DMRB 4.2) gives advice on where they are suitable and on their design.

Effects of Pavement Overlays on Drainage Edge Details

Overlays require raising of verge and central reserve levels, with the following respective implications.

Kerbs and gullies and combined drains

3.20 Necessary associated drainage works comprise bringing up of filter media and gully gratings to new levels. Neither of these activities presents any great difficulty. Alterations in level of precast concrete kerb is more difficult and expensive than the removal and replacement of extruded asphalt kerbing, but is a matter beyond considerations of drainage detail. It may be advisable to consider the relative economics of an alternative solution comprising reconstruction of the adjacent pavement.

Surface water channels

3.21 Raising of surface water channels may be avoidable if the edge of the overlay can be shaped to suit the top of the channel without compromising the structural integrity of the pavement. Alternatively the existing channel could be broken out and replaced at a higher level. This latter solution would be much more expensive, requiring remedial attention to local break-out of the surfacing and base course consequential to removal of the existing channel. There would also be a temporary loss of drainage facility at the carriageway edge if the channel was constructed prior to placement of the overlay.

Porous Asphalt Surfacing Course

3.22 HD 26 (DMRB 7.2.3) and HD 27 (DMRB 7.2.4) set out the standards for the usage of porous asphalt. Advice on appropriate edge of pavement details and guidance on their usage may be sought from the Overseeing Organisation.

Drainage Collector Detail	**Kerbs and Gullies** (See Note 1)	**Combined Kerb and Drainage Blocks**	**Linear Drainage Channels**	**Surface Water Channels**	**Combined Channel and Pipe**	**Combined Surface and Groundwater Filter Drains**	**Over the Edge Drains**	**Grassed Surface Water Channels**
Urban Applications	General usage	Congested public utility services Shallow outfalls Flat long. gradients	Car park areas Adjacent to vertical concrete barriers Nosings of interchanges	Not generally applicable	Not generally applicable	Not generally applicable	Not generally applicable	Not generally applicable
(Reference documents)	(TA 57) HA 102 HA 104 HA 105		TA 80 HA 78					
Rural Applications	Footways within highway verge eg laybys Roundabouts	Flat long. gradients where footways within highway verge Roundabouts	Nosings of interchanges vertical concrete barriers	High-speed roads especially on embankments	High-speed roads especially on embankments where verge space is limited	Especially in cutting verge	In verges (not suitable for embankments constructed of clayey or silty soil)	In verges
(Reference documents)	(See Note 2) (TA 57)		TA 80 HA 78	TA 80 HA 78 (HA 39)	(HA 113)	(HA 39)	(HA 103)	(HA 119)

Notes:

1 Kerbs in this context are precast concrete.

2 Kerbs and gullies are not recommended for rural roads unless footways are located within the verge, or safety barriers or parapets are required.

Table 3.1: General Applications of Edge Drainage Details

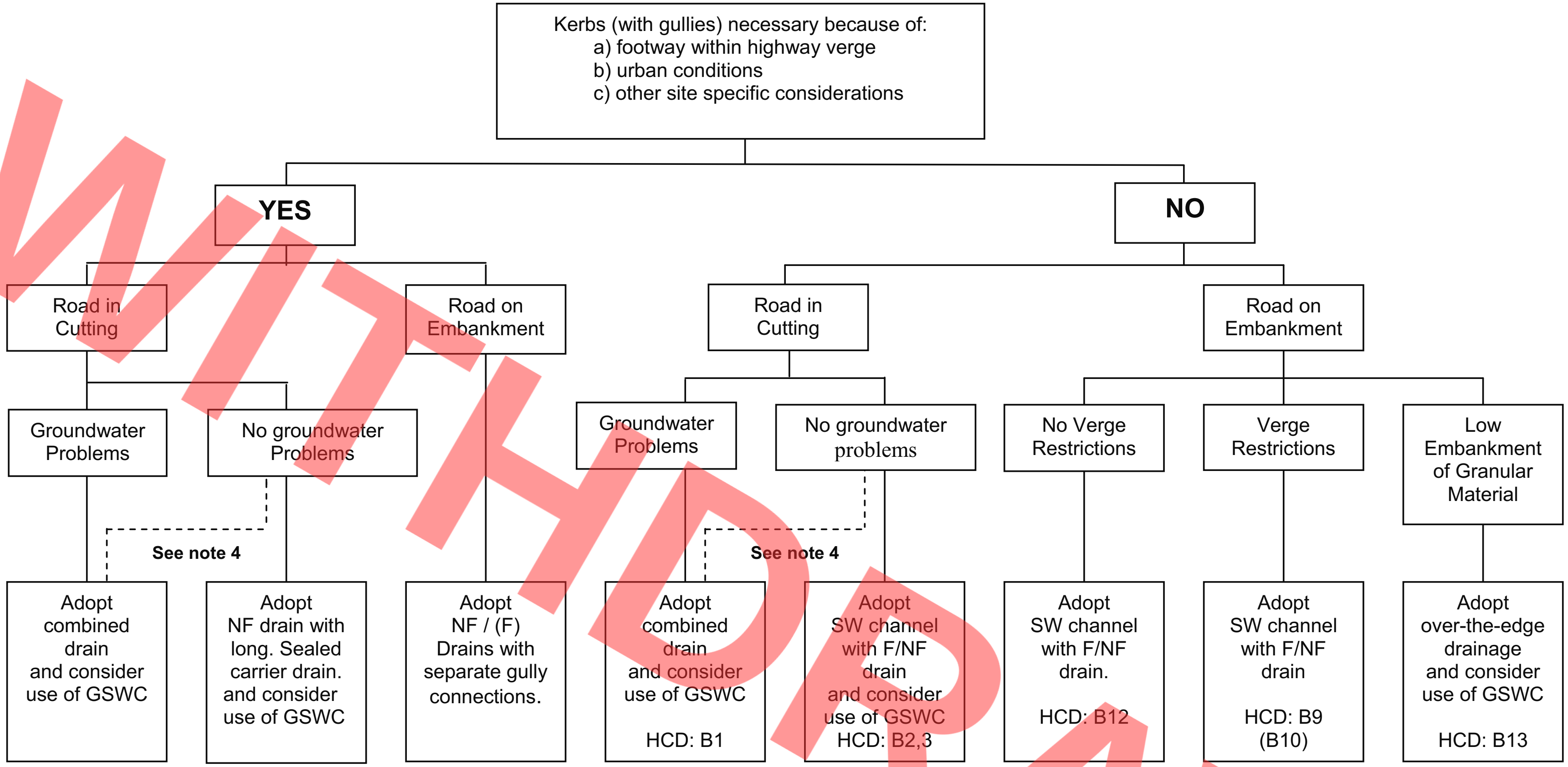

Figure 3.1: Recommended Design Selection Verge-Side Edge Drainage

Note 1: Fin drain usage denoted thus (F) indicates use with road gullies, and should only be permitted if gully connections have no adverse effect on fin drain.
Note 2: NF denotes alternative Narrow Filter Drain.
Note 3: Turf edging between intermittent precast concrete kerb/gully combinations may be acceptable on minor rural roads.
Note 4: This solution can be useful where lack of space inhibits provision of a separate carrier drain + F/NF trench.
Note 5: GSWC denotes Grassed Surface Water Channel.

Volume 4 home page

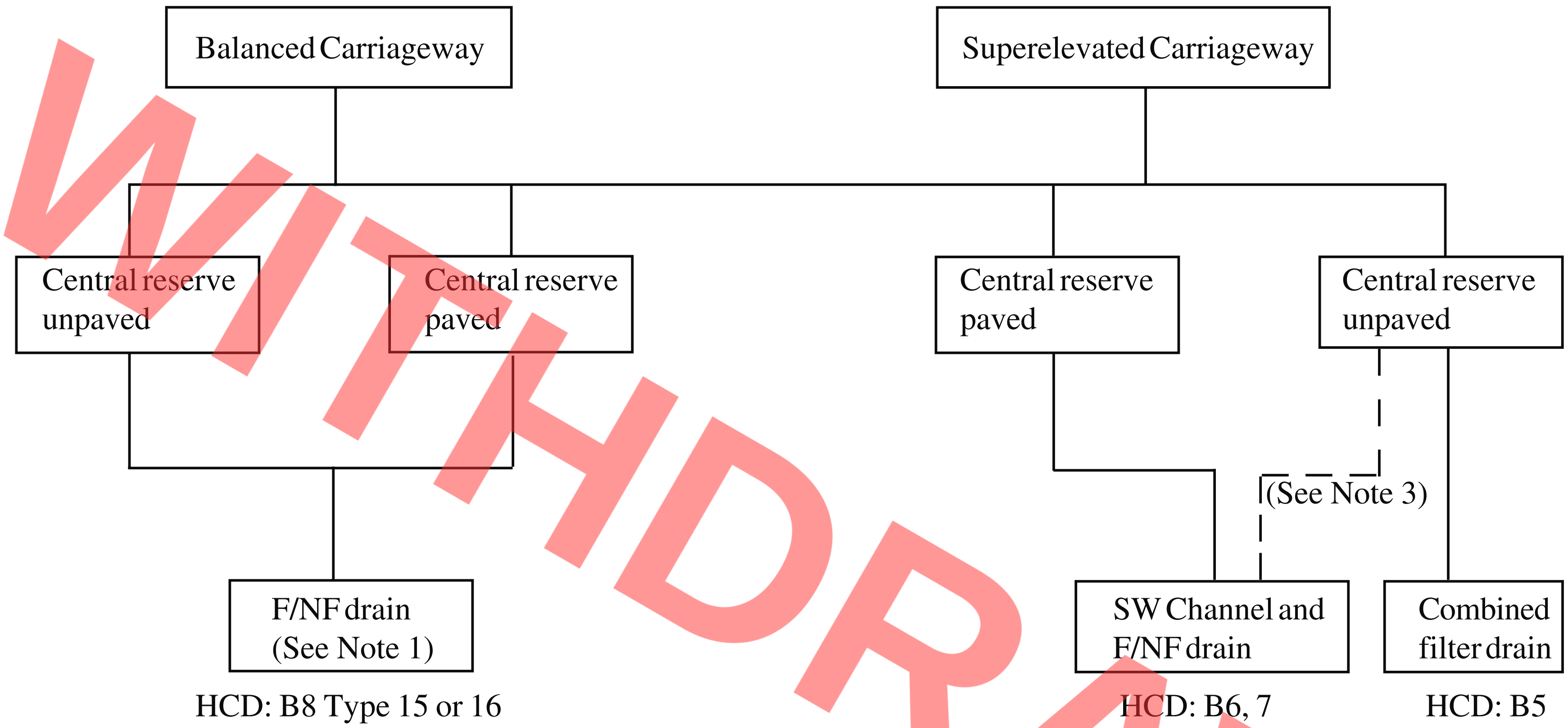

Figure 3.2: Recommended Design Selection Central Reserve Drainage

Note 1: A detail like HCD: B8 Type 14 may be judged preferable for the drainage of wide central reserves.
Note 2: F/NF denotes Fin or Narrow Filter Drain.
Note 3: This is the preferred solution.

Volume 4 home page

MCHW	**DMRB**					
Volume 1: Specification	**VOL 2: HIGHWAY STRUCTURES: DESIGN (SUBSTRUCTURES AND SPECIAL STRUCTURES) MATERIALS**	**VOL 4: GEOTECHNICS AND DRAINAGE**	**VOL 6: ROAD GEOMETRY**			**VOL 7: PAVEMENT DESIGN AND MAINTENANCE**
Volume 2: Notes for Guidance	**SECTION 1: SUBSTRUCTURES**	**SECTION 2: DRAINAGE**	**SECTION 1: LINKS**	**SECTION 2: JUNCTIONS**	**SECTION 3: HIGHWAY FEATURES**	**SECTION 2: PAVEMENT DESIGN AND CONSTRUCTION**
Volume 3: HCD B – Series	BD 30: Backfilled Retaining Walls and Bridge Abutments	TA 80: Surface Drainage of Wide Carriageways HA 39: Edge of Pavement Details HA 37: Hydraulic Design of Road-Edge Surface Water Channels HA 40: Determination of Pipe and Bedding Combinations for Drainage Works HA 78: Design of Outfalls for Surface Water Channels HA 83: Safety Aspects of Road-Edge Drainage Features HA 102: Spacing of Road Gullies HA 103: Vegetated Drainage Systems for Highway Runoff HA 105:: Sumpless Gullies HA 106: Drainage of Runoff from Natural Catchments HA 107:: Design of Outfall and Culvert Details HA 113: Combined Channel and Pipe System for Surface Water Dranage HA 118: Design of Soakways HA 119: Grassed Surface Water Channels for Highway Runoff	TD 9: Highway Design Link	TD 16: Geometric Design of Roundabouts	TA 57: Roadside Features	HD 26: Pavement Design HD 27: Pavement Construction Methods

Table 3.2: Surface Drainage – Guidance Documents

Volume 4 home page

4. SUB-SURFACE DRAINAGE

Introduction

4.1 Sub-surface drainage of highway pavements comprises the measures incorporated in the design in order to control levels of groundwater, and drain the road foundation (see HD 25, DMRB 7.2).

4.2 Requirements for sub-surface drainage are illustrated in Highway Construction Details, MCHW 3. Sub-surface drainage is normally necessary in order to remove any water which may permeate through the pavement layers of roads in both cut and fill situations. This can be achieved on embankments by provision of fin or narrow filter drains illustrated in the B and F Series Drawings of MCHW 3.

> Sub-surface drainage in cuttings must provide not only for the necessary drainage of pavement layers, but also for the removal, to an adequate depth, of any groundwater which may be present in the cutting.

Groundwater may be subject to seasonal variations consequential to rainfall conditions and soil permeability, and the best possible analysis of groundwater conditions should be undertaken during ground investigation. Water moves partly by gravity and partly by capillary action, and these movements are susceptible to control by subsoil drainage.

4.3 Sub-surface drainage is effected by installation of longitudinal sub-surface drains at the low edges of road pavements. These serve to drain the pavement layers and the pavement foundation. They also prevent ingress of water from verge areas adjacent to the pavement.

> It is also essential that water is not retained within the sub-base and for that matter the capping layer. Water reaching the formation and sub-formation must be drained to longitudinal sub-surface drains by adequate shaping of the formation and sub-formation such that no undrainable low spots occur.

Circumstances in which sub-surface drainage may be omitted are described in HD 25 (DMRB 7.2) and HA 39 (DMRB 4.2), but advice should be sought from the Overseeing Organisation in such instances.

4.4 Table 4.1 sets out the documents which give guidance on the provision of sub-surface drainage. MCHW 3 indicates alternative acceptable sub-surface drains in cross-section, and MCHW 1, in conjunction with numbered Appendix 5/1, specifies acceptable construction materials. Implications are dealt with in detail in the text following.

Groundwater Considerations

4.5 HA 44 (DMRB 4.1) advises upon CBR values of subgrade and capping relative to sub-surface drainage conditions. Weak cohesive subgrade material in cuttings will require replacement by capping layer, and the CBR value used to determine the required capping layer thickness required will have been chosen for a particular water table level. That level will eventually be dependent upon the depth of the subgrade drains below sub-formation level. Table 13/2 of HA 44 (DMRB 4.1.1) enables CBR values to be assessed for two conditions of water table level, a 'high' water table of 300mm below formation or sub-formation level, and a 'low' water table of 1000mm below formation or sub-formation level.

4.6 The minimum depth of installation of fin and narrow filter drains is set out in MCHW 3 as DN + 50mm to invert beneath sub-formation level, or 600mm to invert beneath formation level: these levels being defined in Clauses 601.9 and 601.10 (MCHW 1). Where there is no capping layer, the drains should be laid to the lower of those two depths. Drains installed at these minimum depths cannot lower high groundwater to even the 'high' water table level of 300mm below sub-formation level. To achieve even the 'high' water table level will require the fin or narrow filter drain to be installed at an appreciably greater depth than the minimum shown in the MCHW 3. In situations where large volumes of groundwater are anticipated filter drains can provide a better solution than fin or narrow filter drains.

A further consideration is that a fin or narrow filter drain will normally follow the longitudinal profile of the carriageway and it is therefore essential, especially in flat or gently undulating conditions, that the designer ensures that the drains can discharge from all low points to a suitable outfall.

These are important considerations in assessing the applicability or otherwise of fin and/or narrow filter drains rather than combined drains.

Sub-surface Drainage of Roads in Cuttings

4.7 The general philosophy of good highway drainage is that surface water be kept separate from sub-surface water in order to prevent large amounts of water being introduced into the road at foundation level. It is not always practicable to achieve this philosophy. For example, in the case of cuttings there are many benefits that can accrue from the provision of combined filter drains. These include:

i) permissible early installation and usage for collection of drainage runoff during the construction stage, provided construction debris is prevented from blocking the filter media. This could be done, for example, by the use of temporary sedimentation ponds;

ii) removal of groundwater beneath the pavement to a greater depth than would be possible with fin or narrow filter drains;

iii) easier construction than with a solution incorporating both surface water carrier drains and fin or narrow filter drains;

iv) easier inspection and maintenance than is possible with fin or narrow filter drains;

v) facility for collection of water from drainage measures installed separately in the side-slopes of cuttings.

4.8 Combined drains in cuttings may be constructed using pipes with perforations or slots laid uppermost, and with sealed joints to minimise surface water input at trench base level. Trench bottoms may need to be lined with impermeable membranes up to pipe soffit level to prevent addition of water to the sub-soil that may otherwise be dry.

Sub-surface Drainage of Roads on Embankment

4.9 Drainage of pavement layers of roads on embankment is effected by fin or narrow filter drains contiguous to the edge of the pavement as shown in the B-Series Drawings of MCHW 3, and as explained in HA 39 (DMRB 4.2).

Relative Characteristics of Combined and Separate Systems

4.10 HA 39 (DMRB 4.2) requires that restraints imposed upon any choice of drain types should be minimised in order to encourage cost-effective solutions. It does, however, accept that particular types of drains or material may be excluded for sound engineering reasons.

4.11 The differences in principle between combined and separate highway drainage systems are defined in paragraph 1.7 of the Introduction to this Standard. These differences are described in greater detail in the following text.

4.12 A combined system comprises porous, perforated or open jointed non-porous pipes within trenches backfilled with permeable material. These trenches are situated in verges and/or central reserves adjacent to the low edges of pavements such that surface water can run off the pavement directly onto the trench top and then permeate through the drain trench backfill to the drain pipe at the base of the trench. Pavement and capping layers are contiguous with the side of the trench, and any water within these layers is also collected by the drain. Such drains contain a number of variables, primarily pipe types, filter drain backfill material, trench top surfacings and use of geosynthetic membranes and/or impermeable trench treatments as necessary in special cases. The function of the drain with respect to surface water runoff and sub-surface drainage remains identical in all cases. They also have considerable capacity to facilitate the lowering of groundwater and collection of slope drainage from cuttings.

4.13 Separate systems provide for collection of sub-surface water ie drainage of pavement and capping layers, separately from that of surface water runoff from the pavement. The surface water can be collected by several different systems such as surface water channels, combined drainage and kerb blocks, road gullies and linear drainage channels. Sub-surface drainage associated with separate collection of surface water runoff is effected by either fin or narrow filter drains defined in MCHW 1 and MCHW 3 F18. MCHW 2 gives advice on the necessary hydraulic capacity of fin and narrow filter drains.

Combined Drains

4.14 Combined drains have been a traditional solution for many years and possible problems in performance are commented upon in HA 39 (DMRB 4.2). These include those of stone scatter, surface failures of embankments, pavement failures and safety and maintenance problems. Stone scatter from verge drains, where a hard shoulder of 3.3m width separates the verge from the carriageway, may not normally be a problem, but they can present a safety hazard when the hard shoulder is used as running lane in contraflow. Stone scatter from central reserve drains presents a greater safety hazard.

Problems can be reduced by implementation of any of the following measures:

i) spraying of the top surface of exposed filter material with bitumen;

ii) the use of geogrids to reinforce the surface layer of the filter material;

iii) incorporation of lightweight aggregate for filter material at finished level, as permitted in MCHW 3 B15;

iv) possible usage of bitumen bonded filter material in the top 200mm of the trench.

4.15 Combined drains can be advantageously employed in cutting situations requiring appreciable ground water removal. The relatively large hydraulic capacity required for dealing with surface water during heavy storms means that combined drains generally contain sufficient capacity to take any intercepted ground water. Separate design estimates of groundwater flows are not generally necessary.

4.16 Problems may arise with porous concrete pipes used in filter drains. These have lower structural strength than other rigid pipes and their adoption must be checked against this criteria and local experience.

Separate System: Fin Drains

Types 5, 6 and 7 Fin Drains

4.17 Detailed guidance is given in Series NG500 (MCHW 2). It is intended that the widest possible choice of fin drain type should be available to the Contractor.

4.18 It is intended that types 5, 6 and 7 drains be installed in narrow trenches and there can be difficulties in working in very narrow trenches, depending on the type of ground, and in compaction of backfill.

These problems should be alleviated by the use of automatic drain-laying equipment where ground conditions permit. Non-granular materials will permit excavation by continuous trenching machine, provided that the trench remains open sufficiently long for the drain to be installed. In suitable granular materials, installation can be effected by plough and simultaneous drain installation by following ‘box’. Associated hoppers and chutes can place backfill where necessary. Neither of these techniques is suitable for use in coarse non-cohesive materials such as rock capping layer. Installation by open trench may be unavoidable in such materials.

4.19 If it is proposed to use fin drains in conjunction with kerbs and gully pavement edge drainage, care must be taken to ensure that construction of gully connections will not prejudice the integrity of the fin drains. The implications of non-restriction in construction trench width of a Type 5 fin drain should be considered. Consequences of the possible unsuitability of trench arisings as backfill material should also be considered.

Type 10 Fin Drain

4.20 HA 39 (DMRB 4.2) specifies use of a Type 10 drain with rigid carriageways. The designer should decide whether particular scheme specific pavement materials warrant its adoption with flexible construction.

Separate System: Narrow Filter Drains

4.21 Narrow filter drains are intended for use as edge of pavement sub-surface drains and are suitable alternatives to fin drains for that purpose. Guidance is similar to that for fin drains in MCHW 2, but in addition requires that for Type 8 drains ‘the filter materials should be compatible with the adjacent soil or construction layer as the filtration is achieved by the filter material and the geotextile sock around the pipe'. This can be difficult to predict, particularly in the upper layer of embankments. Use of 100mm dia pipes within narrow filter drains, rather than pipes of smaller diameter, should provide benefits with respect to future maintenance and at little or no additional cost.

Pavement Life

4.22 There are factors pertinent to drainage at construction stage that have a bearing upon the life of a pavement. The subgrade material may be subjected to more onerous conditions during the construction stage than during the service life of the pavement, and so must be sufficiently strong to provide an adequate platform for construction of the sub-base. The CBR should not be allowed to reduce from its assumed long term equilibrium to an unacceptable one as a consequence of softening due to the presence of water. HD 25 (DMRB 7.2.2) defines requirements of the road foundation. It is imperative that groundwater drainage and sub-grade drainage should prevent plastic deformation of the road foundations, sub-base and capping layer during construction, and it is recommended that consideration be given towards pre-earthworks drainage in all projects where this might be feasible.

MCHW	DMRB			TRMM (Only applicable in England)
Vol 1: Specification 500 – Series **Vol 2: Notes for Guidance 500 – Series 600 – Series** **Vol 3: HCD B – Series F – Series**	**VOL 4: GEOTECHNICS AND DRAINAGE**		**VOL 7: PAVEMENT DESIGN AND MAINTENANCE**	**VOL 2: ROUTINE AND WINTER MAINTENANCE CODE**
	SECTION 1: EARTHWORKS	**SECTION 2: DRAINAGE**	**SECTION 2: PAVEMENT DESIGN AND CONSTRUCTION**	**Part 1:** Chapter 1.7 Highway Drainage
	Part 1: HA 44 Design and Preparation of Contract Documents Chapter 7 Cuttings: Groundwater Chapter 8 Embankments: Drainage Chapter 10 Sub-grade and Capping:Drainage (paras 25-27) **Part 3: HD 41 Maintenance of Highway Geotechnical Assets** 1. Introduction: General (paras 1.1 & 1.2)	**HA 39 Edge of Pavement Details** Sub-surface drainage (para 3.8) **HA 40 Determination of Pipe and Bedding Combinations for Drainage Works**	**Part 2: HD 25 Foundations** Chapter 2 Subgrade Assessment Chapter 3 Capping and Sub-base (paras 3.27-3.32)	

Table 4.1: Sub-Surface Drainage – Guidance Documents

Volume 4 home page

5. EARTHWORKS DRAINAGE

Toe Drainage and Cut-off Drains

5.1 It is essential that existing land drainage and runoff from external catchments be taken into account in the design of highways drainage. See HA 106 (DMRB 4.2) for specific advice.

The requirements of the appropriate water and drainage authorities should be established to ensure that their rights are accommodated and their reasonable interests safeguarded. Information on ground water conditions must be included in the data obtained from site investigations for proposed major roadworks.

5.2 Where surface water and sub-surface water from adjoining land will flow towards the road, it will generally be necessary to construct intercepting drains at the tops of cuttings and the toes of embankments. In rural areas these may be ditches rather than filter drains because of their greater capacity and comparative cheapness. It is imperative that the geotechnical engineer evaluates the effect of such proposed ditches at an early stage, as large off-sets may be necessary from the toes of embankments to associated toe-ditches. This may affect land acquisition requirements in the draft Compulsory Purchase Order (CPO) for a scheme. It may also affect adjacent land management and the choice of drainage solution. Landscaping measures, especially the inclusion of noise bunds, may influence drainage design.

5.3 It is good practice to carry out drainage works at the earliest possible stage in the construction of any new road. Longitudinal drains should be sufficiently deep to collect whatever drainage is necessary at cut/fill zones and it will be necessary to give special attention to the treatment and collection by sub-soil drains of water from any water-bearing seams which are intercepted by cuttings. Intercepting drains or ditches must be sufficiently deep to intercept any system of severed agricultural under-drainage.

5.4 Watercourses and ditches crossed by a major highway are generally culverted, with the consent of the land drainage authority. It may be more economical to collect flows from minor ditches into longitudinal highway drains, but such decisions are complex and involve considerations of relative levels, availability of an adequately large outfall watercourse, land drainage authority consents, and possible compensation for loss of water downstream of the road. HA 106 (DMRB 4.2) provides specific advice on dealing with the drainage of natural catchments and HA 107 (DMRB 4.2) gives detailed advice on outfall and culvert design.

5.5 Where it is necessary to provide slope drainage in cuttings a longitudinal piped drainage system will be required in the verge. This will be able to collect the slope drains without the possibility of any detrimental effect to sub-surface drainage of the pavement. A drainage system comprising a surface water channel with an associated fin or narrow filter drain, and no longitudinal pipe drain, could not be used to collect slope drainage. It would be necessary to provide, in addition, a longitudinal carrier drain, or dispense with the fin or narrow filter drain and provide a filter drain, or alternatively use a combined surface and ground water drain without a surface water channel.

5.6 The need for slope drainage should be determined prior to the start of construction in order to minimise difficulties in the future connection of slope drains into longitudinal verge drains.

Drainage to Retaining Structures

5.7 Requirements for drainage of retaining structures are set out in BD 30 (DMRB 2.1).

6. DETAILED DESIGN, PAVEMENT EDGE DRAINAGE

Introduction

6.1 Detailed design of pavement drainage comprises five basic aspects:

i) determination of the design storm that should be used in the design of the drainage elements within the catchment under consideration;

ii) calculation of the flows from the design storm at each drainage element within the catchment;

iii) establishment of the hydraulic adequacy of each drainage element within the catchment;

iv) determination of the location of the outfalls or soakaways; and

v) determination, where necessary, of structural loadings upon drainage conduits, and verification that each conduit will withstand the loading placed upon it.

Storm Return Period

6.2 Longitudinal sealed carrier drains must be designed to accommodate a one-year storm in-bore without surcharge. The design must be checked against a five-year storm intensity to ensure that surcharge levels do not exceed the levels of chamber covers.

Combined surface water and groundwater drains must also be designed to accommodate a one-year storm in-bore without surcharge. A design check must be carried out to establish that a five-year storm intensity will not cause chamber surcharge levels to rise above the formation level, or sub-formation level where a capping layer is present. In carrying out this check it should be assumed that pipes are sealed and that back flow from pipes into the filter media does not take place.

6.3 Guidance on the design of surface water channels is given in HA 39 (DMRB 4.2). The fundamental philosophy of this document is that a design storm with a return period of one year must be contained within the channel, and that surcharge consequential to a storm of five-year return period should not encroach into the carriageway.

Channels must be designed to accommodate a 1 in 1 year storm with the flow contained within the channel cross section without surcharging. The allowable surcharge widths must then be checked for 1 in 5 year storm.

In verges, surcharges under a 1 in 5 year storm must be limited to a width of 1.5m in the case of hard shoulder and 1.0m in the case of hard strip.

In central reserves, surcharge under a 1 in 5 year storm must not be permitted to encroach the carriageway, but flooding within the non-pavement width of the central reserve is permissible providing there is safeguard against flows from the surcharged channel overtopping the central reserve and flowing into the opposing carriageway.

Allowance for climate change: The rainfall intensities used to calculate the design storms must include an allowance for the effects of climate change. Where rainfall data exclude such an allowance, a sensitivity test on the design of the drainage system must be carried out by increasing rainfall intensities of the design storm by 20%.

6.4 Application of storms of other return periods should be tempered by considerations of geography and particular highway geometry. Examples of critical sections of road are quoted in HA 37 (DMRB 4.2) as:

i) applications of superelevation that cause crossfall to be locally zero; and

ii) sections of road draining to longitudinal sag points where it is important to prevent flooding.

This is especially important for longitudinal sags in cuttings, where it may for example be deemed prudent to design outfall drainage to a design storm return period of say ten years (i.e. having an annual probability of 10%). These are matters for engineering judgement relative to the drainage elements under consideration, and the consequences of surcharge of the system in its unique situation.

Calculation of Runoff Flows

6.5 Having determined the relevant design storm frequency that should be used, it is necessary to determine the storm that will give maximum runoff at the various locations within the catchment.

6.6 Over the years, drainage designers have been using a number of established procedures (ref . 7) for calculating runoff. However, the most commonly used procedure in the UK is the Wallingford Procedure first published in 1981 (ref. 9). This comprises a number of methods and one of these, the Modified Rational Method, gives a value of peak discharge only and no indication of runoff volume or hydrograph shape. It is recommended within the Wallingford Procedure that catchments to be analysed by this Method should not exceed 150 hectares, with times of concentration of up to about 30 minutes and outfall pipe diameters of up to about one metre.

The Wallingford Hydrograph Method is a computer-based hydrograph method incorporating separate models of the surface runoff and pipe-flow phases. Storm overflows, on-line and off-line tanks and pumping stations may be represented. The Method is appropriate to the majority of applications. Peak flow discharges obtained by the Modified Rational Method and Wallingford Hydrograph Method are of comparable accuracy. Data input requirements are similar for both methods.

6.7 A number of commercial programs based upon the Wallingford Procedure are available and suitable for highway drainage design. Programs selected for use should be able to design a system to a particular storm intensity, and permit analysis of the system under surcharged conditions. Details of these programs and their use are given in DMRB 11.3.10.

Gully Systems

6.8 Gully systems are based upon the collection, by road gully, of surface water runoff which has been shed towards the edges of a road pavement and which flows along a road channel in front of a raised kerb until it is collected by a gully.

The spacing of road gullies is determined by considerations of the maximum width of flow that can be permitted in a channel fronting a raised kerb. Advice on gully design spacing is set out in paragraphs 2.7 and 2.8. It is necessary for the Designer to include details of gully grating specifications in the Contract in Appendix 5/1, and the comments in 6.9 are pertinent to structural considerations of traffic loadings to which gullies are subject.

6.9 The nose sections of junction merge and diverge tapers commonly have low points in cross-section due to the direction of crossfalls of the slip roads and main carriageways and because of similar corresponding channel levels. Drainage elements placed within these tapers should be designed to withstand trafficking of the hard shoulder during maintenance operations.

Surface Water Channels

6.10 Design of surface water channels is described in principle in HA 39 (DMRB 4.2). Design of the channels in cross-section to achieve the necessary hydraulic capacities is set out in HA 37 (DMRB 4.2); cross-sections are illustrated in the MCHW 3 B Series Drawings. The design technique is essentially a method by which the required size or distance between outlets for channels is determined taking into account local rainfall characteristics.

6.11 Surface water channels generally occupy a larger proportion of the available verge or central reserve width than do other common drainage systems. This is particularly the case for wide motorways with a verge width of 1.5 metres, where transverse areas of impermeable pavement are proportionately larger and the unpaved width of verge much less than that of trunk roads. Other features within verges and central reserves such as safety fences, services, lighting columns and signs impose further restrictions upon maximum channel sizes which can be constructed. The achievement of long channel lengths may also be prevented by necessary discontinuations at piers, abutments, slip roads, junctions, laybys, central reserve crossover points or emergency crossing points. Changes of superelevation also constitute points of termination of channels. The surface drainage of wide carriageways is described in TA 80 (DMRB 4.2).

6.12 It is necessary to outfall surface water channels whenever they reach capacity, and if suitable outfalls are not available carrier pipes become necessary. Discharge into carrier pipes will be unavoidable in cuttings more than a few hundred metres in length.

When discharge into a longitudinal carrier pipe has become necessary, access chambers are normally required at 100m intervals. These provide convenient discharge points for channel outfalls via suitable aprons and gratings within the channel invert. They also enable incorporation of smaller channel sections that can be more easily accommodated within the available highway cross-section.

6.13 The design method of HA 37 (DMRB 4.2) is based on kinematic wave theory and takes account of variations in rainfall and flow conditions with time. For the purpose-built surface drainage channels, HA 37 (DMRB 4.2) should be used to determine the spacing between the outlets, which, in turn, should be designed according to the recommendations of HA 78 (DMRB 4.2).

Combined Kerb and Drainage Blocks

6.14 Combined kerb and drainage blocks were commented upon in principle in Chapter 3. Specification for these blocks is set out in MCHW 1. This requires the Designer to specify particular requirements with respect to dimensions and strength of the units and their hydraulic design parameters, and the Contractor to design the system. The Designer should obtain the approval of the Overseeing Organisation to the content and inclusion of the Specification which he requires. Proprietary combined kerb and drainage blocks should be examined, and in the interests of commercial benefit the specification should be as wide as possible to maximise competition.

6.15 Each manufacturer produces comprehensive literature of the product and this will include statements and a design guide to the hydraulic capacity of his product. The Designer should be aware that the claimed hydraulic capacities may have been derived on a simplistic basis, normally based on the Colebrook-White equation for open-channel flow. The effect of turbulence from the entry of flow at each inlet to the blocks will be detrimental to the flow conditions and may or may not have been taken into account. For several reasons an equable comparison of the relative practical performance of kerbs and gullies, surface water channels and combined kerb and drainage blocks is not possible. Different flow theories are used in each case, the most extreme disparity being that part flooding of the carriageway is accepted and essential in the operation of a kerb and gully system, whilst no such flooding is taken into account in manufacturers' claims for capacities of combined kerb and drainage blocks. The Designer will need to be satisfied with the design recommendations provided by the manufacturers. However, it is unlikely that outfalls designed accordingly will give rise to under-performance in practice. The designer should examine the basis of claimed hydraulic capacities and the corresponding outfall spacings.

Manufactured Linear Drainage Channels

6.16 MCHW 1 sets out the specification for linear drainage channels. Manufactured units have been available in the UK for a number of years and have been used extensively for the drainage of large paved areas, notably car parks. One of the two common types of system is based on a trough or channel made of concrete, polymer concrete, glass reinforced concrete or other similar material. Cast iron and steel systems are also available. Troughs are covered by some form of grating, which will be either integral with the channel or a separate element which is bolted or otherwise fixed to the channel. The other common system comprises concrete blocks, typically 300mm square in section and 600mm to 900mm in length. These are cast with an internal cylindrical cavity such that a continuous pipe is formed when units are laid together. Water is admitted through either a continuous slot or through frequently spaced holes in the top face. Side entry inlets may also be specifically incorporated for use as edge drainage with porous asphalt surfacing.

> 6.17 Use of linear drainage channel units in trunk roads or motorways will require the approval of the Overseeing Organisation.

Such approvals have generally only been granted for use in nosings and crossover situations and in locations which are unlikely to be trafficked. Restrictions will be placed upon the usage of manufactured units which require the mechanical interlocking of a grating to the trough section of a unit. Some units may also be unsuitable for areas of pedestrian and cyclist usage. Manufactured units have been more extensively used on the Continent than in the UK and it is possible to obtain proprietary products with comprehensive ranges of fittings. Manufacturers will claim hydraulic characteristics and performance of their products. Performance of the units must be compatible with calculated design runoffs from the pavement into the proposed linear drainage systems and the proposed outfalls from those systems.

In Situ Concrete Linear Drainage Channels

6.18 This form of construction has been extensively used, primarily by slip forming, on major roads on the Continent. Development and practice in the UK has been more recent, and has only been trialled on limited schemes. These channels comprise formation of a longitudinal cylindrical conduit within an in situ concrete block approximately square in cross-section. Longitudinal slots formed in the block above the conduit transmit surface-water run-off into the conduit beneath, and the form of these units is thus very similar to one of the manufactured types of channel described earlier. These units are normally constructed by slip forming, the longitudinal conduit being generally formed by inflated plastic tubes which are later removed, or by a PVC pipe which is left in position. The longitudinal slots overlying the conduit are formed by slip-forming.

6.19 Specification in practice is based primarily upon the 1100 Series (MCHW 1) clauses and the Code of Practice 'BS5931. Machine laid in situ edge details for paved areas' (ref 4). It is necessary that the construction be structurally adequate, and the slip formed channels generally incorporate longitudinal reinforcement.

6.20 There are considerable differences in the tolerances and quality control that can be achieved with in situ construction relative to pre-cast. In the meantime, in situations where a linear drainage slot-type channel is desired, the Overseeing Organisation would be able to provide guidance on current best-practice. It is possible that this form of construction will be well suited for installation alongside slip formed vertical concrete barriers (VCBs) as construction of these becomes more common.

Combined Channel and Pipe Systems

6.21 Guidance on the hydraulic and structural design of combined channel and pipe systems is given in HA 113 (DMRB 4.2). They comprise surface water channels with an internal pipe formed within the base of the units that is able to carry additional flow. The systems are particularly well suited to in situ construction in concrete using slip forming techniques, although they can also be constructed using other methods. Use of such systems can remove the need for a separate carrier drain in the verge and can enable flow to be carried longer distances between outfalls. If no carrier drain is required, more space can be made available in the verge for other services.

Pipe Design

Hydraulic

6.22 Hydraulic design of a pipe network is generally accomplished by computer application of the principles described earlier in this Chapter. Cross-carriageway pipes, which discharge flows from the central reserve to the verge and thence to outfall, should have sufficient spare capacity to ensure that storms in excess of the design storm will not cause surcharges of the central reserve drainage. Cross connections should be adequately sized to avoid this. Considerations of provision of some spare capacity are relevant to all outfall pipes, which, in surcharge conditions, may otherwise jeopardise the safety of the highway.

Structural

6.23 Guidance on the structural design of pipes is set out in two publications:

i) A Guide to Design Loadings for Buried Rigid Pipes (ref. 5); and

ii) Simplified Tables of External Loads on Buried Pipelines (ref. 8).

> Guidance on permissible combinations of pipe and bedding materials applicable to MCHW is set out in HA 40 (DMRB 4.2).

This document guides the selection of pipes in trenches with cover depths between 0.6m and 6.0m, and with diameters from 100 to 900mm in carrier drains and from 100 to 700mm in filter drains. Pipe materials covered within the document include rigid pipes of vitrified clay, precast concrete and asbestos cement, and flexible pipes of upvc. MCHW 2 guides upon necessary specifications for plastics pipes, and also upon exclusions or special treatments necessary to withstand chemical attack because of groundwater conditions.

6.24 Analysis of pipes outside of this range will require recourse to other guidance documents, but this should not generally be necessary at design stage. Where it is necessary to lay pipes beneath carriageways with very shallow depths of cover the characteristics of ductile iron pipes should be borne in mind. These are semi-flexible and able to withstand high loadings, not just in the permanent situation, but also during construction. Guidance on structural strength and loadings can be obtained from manufacturers. A useful recent publication guiding upon characteristics and design of a broad range of pertinent drainage materials is the "Materials Selection Manual for Sewers, Pumping Mains and Manholes" published in January 1993 by the Foundation for Water Research (ref. 6).

6.25 MCHW Volume 1 permits the use of other types of pipe, such as twin-walled PVC, provided that they are supported by a British Board of Agrément Roads and Bridges (BBA R&B) Certificate. Bedding combinations for such pipes are not included in HA 40, but will be specified in the BBA R&B Certificate.

CCTV surveys of drains

6.26 MCHW 1 specifies requirements for testing and cleaning of drains, and includes for testing by spherical mandrel. It also requires that unless otherwise required in Appendix 90/1, carrier, foul and filter drains (but excluding fin and narrow filters drains) shall be surveyed by Closed Circuit Television (CCTV) in accordance with the relevant requirements of SD 15 (MCHW 5.9).

Discharges to Outfalls and Soakaways

6.27 A balance needs to be struck when considering whether road runoff should be discharged to surface waters or to ground. In some cases the effect on receiving surface waters could be such that discharge to ground may be appropriate. This could apply where the discharge would aggravate an existing flooding risk, or where it could have a potentially disproportionate effect on pollution within the receiving waters. Advice on the design of outfalls and culverts is given in HA 107 (DMRB 4.2).

6.28 Advice on the design and construction of soakaways is given in HA 118 (DMRB 4.2). A number of factors must be considered in their design:

i) soakaways must not allow direct discharge to groundwater, for example via boreholes;

ii) soakaways must not be sited within 5m of a building;

iii) soakaways must not lead to a risk of instability, either by washing out of fines, or of saturation of road foundations due to inadequate capacity;

iv) soakaways must not increase the risk of groundwater flooding.

6.29 Designers must ensure there is adequate, safe access to soakaways for maintenance for both operatives and plant. Provision must be made for all maintenance operations to be carried out without disruption to traffic.

7. CONTROL OF POLLUTION AND FLOODING

General

7.1 Whilst the primary aims of drainage systems are to provide rapid removal of surface water from the road surface and to provide effective sub-grade drainage, the systems should also provide some degree of control over the risk of either pollution of the receiving watercourse or flooding elsewhere in the catchment. Guidance on the assessment of these risks is given in HA 216 (DMRB 11.3.10). Table 7.1 shows which systems can provide some form of control over these risks, as well as their compatibility with vegetated drainage systems.

7.2 Systems with the potential for control of pollution or flooding include:

- **Spillage control**: Oil Separators, Lined Ditches, Penstocks, Baffles, Kerbs and Gullies, Surface Water Channels, Filter Drains;

- **Other pollution control**: Filter Drains, Unlined Ditches, Oil Separators, Sediment Traps;

- **Flow control**: Filter Drains, Carrier drains (oversize), Ditches, Combined Kerb and Drainage, Permeable Pavements;

- **Vegetated systems**: Ponds, Infiltration basins, Wetlands, Grassed channels, Swales.

7.3 Where risks of potential pollution or flooding have been identified and the need for controls identified, the use of vegetated drainage systems should be considered in the first instance. Guidance on these systems in given in HA 103 (DMRB 4.2). Guidance on grassed surface water channels for highway runoff is given in HA 119 (DMRB 4.2). There may be situations where limited space restricts the use of vegetated systems and in these cases, the use of conventional drainage systems, either independently or in combination with vegetated systems should be considered. Designers should ensure that systems such as oil separators and lagoons, that may be remote from the highway, are provided with safe means of access for maintenance.

7.4 The degree to which drainage systems and a combination of systems can reduce the pollution in routine runoff is illustrated in Table 7.2, which is taken from a study carried out by The Water Research Centre (WRc) (ref. 10) to determine treatment efficiencies of a range of systems. The table highlights the performance efficiencies of individual components of a drainage system as well as overall system efficiency for 5 sites in England. It will be noted that in some instances a negative efficiency was recorded within a discrete component of the system. This indicates the potential for pollutants to remobilise within component systems as a result of high velocity flows entering a system. Whilst the findings from this study are instructive the scope of the study was limited and the figures are given to indicate rather than prescribe the range of treatment efficiencies of certain systems.

Drainage Systems

Kerbs and Gullies

7.5 Gully pots can have both beneficial and negative impacts on water quality for receiving watercourses. The main benefit from gully pots is their ability to capture potentially contaminated sediments during normal rainfall events prior to discharge into a receiving watercourse. They are more effective at trapping the coarse sediments than the finer ones. They can also provide a good first line of defence in the event of an accidental spillage.

7.6 High inflow rates can cause re-suspension of sediments within the gully pot and subsequent discharge of the liquor from the gully pot can result in a pollutant flush into the receiving drainage network or watercourse. It has been found turbulence in the sump causes mixing of any trapped oils with the water being discharged. The best way of avoiding such re-suspension or mixing of oils is to ensure that the gradient of the pipe leading to the gully is as shallow as possible, consistent with adequate hydraulic performance. Where this cannot be achieved, sumpless gullies may be an option to be considered. HA 105 (DMRB 4.2) provides specific advice on this type of gully.

Surface Water Channels and Drainage Channel Blocks

7.7 In situations where channels are not self-cleansing, deposition of gross pollutants and sediments is likely to occur. Increased sediment build-up potentially poses a safety threat to the travelling public, due to runoff ponding behind deposited materials. To avoid this, gradients of long lengths of these channels should be designed to ensure that they are self cleansing, with sediments being deposited in a downstream system. Channels can be designed to allow for pollution control by emergency response kits, such as those used by Environment Agency personnel. These can be rapidly deployed to form a watertight seal at gully gratings, preventing discharge of runoff to the drainage network.

Combined Kerb and Drainage

7.8 Combined kerb and drainage systems can attenuate flow, mainly due to the high storage capacity of the design. Where storage or balancing ponds are proposed as part of the design, the use of combined kerb and drainage systems can help to reduce the size of, and sometimes eliminate the need for, an attenuation pond.

Piped Systems

7.9 In the event of accidental spillage, piped systems can provide a form of spillage containment if adequate downstream control is provided. This could take the form of a penstock, handstop, or an orifice that can be readily blocked in emergency.

Ditches

7.10 Ditches have the potential to control pollution, due to infiltration of the runoff through any vegetation present. Ditches with gentle side slopes can be considered to have similar properties to swales, which are described in HA 103 (DMRB 4.2). Ditches with concrete or similar facing will not have the same potential, but can be adapted to contain spillages. A lined ditch can act as a containment basin if located between the road drain and the receiving watercourse. It should have a minimum of 25m^3 capacity and have a downstream control that can be shut or blocked in the event of accidental spillage of pollutants on the road. Where ditches are located above permeable strata, there is a risk that highway runoff will infiltrate and contaminate any underlying aquifer. This can be prevented by facing the ditch with concrete/ impermeable liner or placing the impermeable liner beneath it.

Over-the-edge Drainage

7.11 Over-the-edge drainage can provide, in some circumstances, an effective form of pollution control as highway runoff is allowed to filter through vegetation on the slope. As with ditches, however, there is the risk of infiltration and contamination of groundwater. In such locations the toe ditch should be lined to prevent such pollution. Pollution control is also possible with this drainage system using a downstream control.

Combined Filter Drains

7.12 Combined drains offer some protection against release to receiving water of accidental spillages, as they can delay the release of pollutants. However once polluted effluent has entered the carrier pipe, pollution control is very limited without downstream controls such as penstocks. The filter media can also adsorb suspended solid pollutants and heavy hydrocarbons, reducing downstream pollution risk from routine runoff. In locations where the routine runoff causes a build-up of pollutant in the filter media, it may be necessary to renew the filter material every ten years to ensure it remains sufficiently permeable. This will probably be needed if contaminated by a serious accidental spillage.

7.13 The use of combined filter drains should always be assessed in conjunction with the risk to groundwater pollution. Impermeable trench liners may be appropriate where groundwater pollution risks are high.

Oil Separators

7.14 There are two main types of oil separator: the full retention separator and the bypass separator. Their primary function is to remove oil from the water column, but they are less effective at removing soluble oils or other water-soluble liquids.

7.15 Full retention separators are used where all the runoff has to be treated. Their application will be very rare on highways, and their use is usually reserved for locations such as garage forecourts. Exceptionally, they may be used in maintenance depots or construction sites, and where the receiving environment is especially sensitive.

7.16 Bypass oil separators are designed to capture and control flows from rainfall events of up to 5mm/hour, which is about 10% of the typical peak rainfall intensity in the UK. They rely on the greatest pollutant load being carried by the "first flush" of a runoff event. Only 1% of all rainfall events in the UK have a rainfall intensity exceeding 5mm/hour, so such interceptors will cater for the large majority of events.

7.17 On rural highways, oil separators may not be the optimum solution, due to their requirement for frequent maintenance. Consideration should be given to installing a vegetated drainage system, as described in HA 103 (DMRB 4.2), or to a less expensive containment facility.

Other Containment Facilities

Sedimentation Lagoons and Tanks

7.18 These structures should be constructed above flood plain level, if they are required to provide storm water control. Aquatic growth in lagoons will act as a filtering mechanism for suspended particles and pollutants. Incorporation of by-pass facilities may be possible such that only the first flush runoff is given full settlement, subject to consultation with the regulatory authority. For more advice on the design and selection of settlement lagoons see HA 103 (DMRB 4.2).

Pollution Control Devices

Penstocks

7.19 Penstocks comprise a flat plate, fitted to a pair of guide slots on a headwall or chamber wall, which is raised and lowered using a screw thread operated by a wheel. During routine highway operation, penstocks should be in the fully raised position, and have no influence on flow passing through the drainage system. The primary function of penstocks is to control spillage incidents. If lowered in time prior to discharge of significant quantities, penstocks can potentially retain 100% of spilled material, which are then relatively easily removed by suction or other methods, depending on the material involved. Operation of penstocks should only be by either emergency or EPA personnel, or highway maintenance contractors. Designers must ensure that such devices can be readily located and that they are provided with safe and easy means of access (see Chapter 8).

7.20 If the penstock is lowered over the pipe opening for any other reason, potentially due to vandalism, failure of the screw thread or plate, or not being raised after an incident, the penstock will retain storm water flow, which is likely to result in flooding, or scouring following a breach of the headwall or ditch. Regular inspection and maintenance will be required to ensure they do not become inoperable through long periods without use and to check they are not being vandalized.

Handstops

7.21 Handstops are similar to penstocks except the plate is raised and lowered directly, not using a screw thread. The design should ensure that their use will not be compromised by the need to lift the plate manually. They will generally be cheaper than penstocks, but not as suitable for locations requiring a larger system. As with penstocks, regular inspections and maintenance will be required.

Weirs, baffles

7.22 Weirs and baffles can act as both pollution and flood control devices. Where they are required to reduce spillage pollution risk, they should be designed with a notch or orifice that can readily be blocked by a sandbag in an emergency. Weirs can act as a flow control device by allowing excess flows to overtop the weirs. These flows can then be channelled to attenuation ponds or other flood storage systems.

7.23 Baffles can be placed in open channels or ditches to slow down the flows, and therefore attenuate the discharge. Like weirs, they can be adapted to allow them to be blocked in emergency, thus retaining accidental spillages. Where baffles are used for spillage control, there should always be at least 25 m^3 of containment.

Hanging Walls

7.24 Hanging walls comprise simple baffles constructed across open ditches, so that oils and other non-miscible pollutants are retained. The ditch will have a reduced invert level downstream, so that the flow is siphoned beneath the baffle. Careful attention will need to be given to the location, ditch gradient and potential storage capacity of the system. Access for emergency or maintenance personnel will be required.

Flow Control Devices

7.25 Where attenuation of a flow is required, a device such as a vortex chamber can be installed downstream of a pond, ditch, drain or other storage facility, which will have to be designed with adequate storage capacity. These flow control devices should be designed for the specific job they are required to perform. Manufacturers are usually able to provide design details. For some locations, an orifice plate will suffice.

Permeable Pavements

7.26 Full depth permeable pavements allow surface water to infiltrate into the subgrade or to be captured for controlled release off site. With proper design and installation, they can provide an economical solution for management of storm water.

7.27 Traffic levels on motorways and trunk roads require strong pavements and permeable pavements can only be constructed as a departure from standard. There may however be paved areas remote from the running lanes that can be constructed using permeable pavements.

7.28 Permeable pavements are becoming increasingly common in the construction of estate roads and car parks because of their ability to allow surface water to infiltrate into the sub-grade or to be captured for controlled release off site. These pavements are constructed with porous asphalt surfacing overlying a thick gap-graded sub-base, which can temporarily store water. Where infiltration directly into the sub-grade is permitted, no special collection system will be required. As with all such proposed infiltration, the risks to the ground water regime should be carefully assessed.

7.29 Where the existing sub-grade is impermeable, or where infiltration into the ground would lead to unacceptable risks, the water held in the sub-base will have to be drained using appropriate sub-surface drainage adapted to cater for the larger flows expected. Impermeable linings are likely to be required to prevent water reaching sensitive ground waters, unless there is a sufficient existing thickness of impermeable material. The design should ensure that the water will not lead to long term deterioration of the foundation.

7.30 It should be noted that permeable pavements are prone to blockages by debris and this may have a requirement for frequent cleaning. Proper consideration should be given to the provision of safe and convenient access for suitable machinery to carry out this task. The use of permeable pavements on major highways is a new technology. Where their use is being considered, further guidance should be obtained from the Overseeing Organisation.

Conventional Drainage Systems	Potential for Spillage Control	Potential for Pollutant Removal	Potential for Storm Water Control	Compatibility with Vegetated Drainage Systems				
				Grassed Channels (Swales)	Constructed Surface Wetlands	Balancing/ Sedimentation Ponds	Ponds	Hybrid Systems
Distribution Systems								
• Kerbs and Gullies	♦	♦			♦	♦	♦	♦
• Surface Water Channels	♦			♦	♦	♦	♦	♦
• Combined Kerb and Drainage			♦		♦	♦	♦	♦
• Piped systems	♦		♦		♦	♦	♦	♦
• Ditches (Unlined)		♦	♦	♦	♦	♦	♦	♦
• Combined Filter Drains	♦	♦	♦	♦			♦	♦
• Ditches (Lined)	♦		♦		♦	♦	♦	♦
Separators								
• Oil Separators	♦	♦		♦	♦			♦
Pollution Control Devices								
• Penstocks	♦					♦	♦	♦
• Weirs and baffles	♦		♦	♦		♦	♦	♦
Flow Control Devices								
• Flow Regulators			♦		♦		♦	♦
Soakaways		♦		♦	♦	♦	♦	♦

Table 7.1: Runoff Management Capabilities of Conventional Drainage Systems and Compatibility with Vegetated Drainage Systems

Volume 4 home page

Road	Site/Treatment Devices		% Reduction: Inlet to Outlet		
			Initial Form of Treatment	Second Form of Treatment	Total System Treatment
A34	Bypass oil separator/surface flow wetland/wet balancing pond	Metals PAHs TSS	15 -1 37	11 99 73	24 99 83
A34	Filter Drain	Metals PAHs TSS	7 52 38		7 52 38
M4	Oil trap manhole/Sedimentation Tank	Metals PAHs TSS	-7 -30 -19	41 -26 43	30 33
M40	Full retention oil separator/wet balancing pond	Metals PAHs TSS	19 13 -9	35 50 62	48 57 58
A417	Bypass oil separator/dry balancing pond	Metals PAHs TSS	27 4 56	39 16 -37	56 22 40

Table 7.2: Indicative Treatment Efficiencies of Drainage Systems

Volume 4 home page

8. SIGNING OF POLLUTION CONTROL DEVICES

Introduction

8.1 This chapter gives guidance to the signing of pollution control devices. The sign is intended to enable the emergency services to locate the pollution control device as quickly as possible. It is not a traffic sign within the meaning of section 64 of the Road Traffic Regulation Act 1984 and the Roads Traffic Regulations (Northern Ireland) 1997.

The Design of Pollution Control Device Signs

8.2 The sign must be designed in accordance with BS EN 12899-1 'Fixed, vertical road traffic signs Part 1: Fixed Signs' (ref 11).

8.3 The location of the sign must be within the highway boundary and must be referenced in the drainage database described in HD 43 (DMRB 4.2).

8.4 The sign should be located at least 600mm from the edge of a single carriageway or at a hardened verge and 1500mm on high-speed dual carriageway or motorway. Locations other than at the edge of the carriageway are subject to approval by the Overseeing Organisation. The mounting height of the sign should be at least 900mm above the highest point of the carriageway and can be increased up to 1500mm where excessive spray is likely to occur around the sign.

8.5 As this sign is regarded as a notice for the emergency services, the sign face is to have a light green background with white legends and a yellow border (see Figure 8.1). The X-height of the sign is to be 50mm.

8.6 Illumination of the sign is not required. However, the sign face shall be made of retro-reflective Class 1 material.

8.7 The sign should give details of the location of the pollution control device as referenced in the data management system. HD 43 (DMRB 4.2) gives details of how such systems should be managed.

Maintenance of Pollution Control Device Signs

8.8 The sign must maintain its visibility to be effective.

8.9 It should be checked at least annually for signs of discolouring or deterioration of the sign face. Inspections of such signs should include inspections carried out after dark and replacement and/or repairs of signs should be initiated if necessary. Further advice is given in TD 25 'Inspection and Maintenance of Traffic Signs on Motorway and All-Purpose Trunk Roads' and the Traffic Signs Manual Chapter 12: Maintenance of Signs.

Diagram No. 1.1			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	190mm
Material	CLASS 1	Area	0.06 sq. m

Diagram No. 1.2			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	310mm
Material	CLASS 1	Area	0.10 sq. m

Diagram No. 1.3			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	410mm
Material	CLASS 1	Area	0.13 sq. m

Diagram No. 1.4			
Legend	WHITE	X-Height	50mm
Background	LIGHT GREEN	Width	320mm
Border	YELLOW	Height	410mm
Material	CLASS 1	Area	0.13 sq. m

NOTES The sign shall be designed in accordance to BS EN 12899-1:2001

Figure 8.1: Signing of Pollution Control Devices

Volume 4 home page

9. REFERENCES

1 **Trunk Road Maintenance Manual: Volume 2 Routine and Winter Maintenance Code (TRMM2)**

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

Specification for Highway Works (MCHW 1)

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

Highway Construction Details (MCHW 3)

3 **Design Manual for Roads and Bridges (DMRB)**

BD 30 Backfilled Retaining Walls and Bridge Abutments (DMRB 2.1)

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

HA 39 Edge of Pavement Details (DMRB 4.2)

HA 40 Determination of Pipe and Bedding Combinations for Drainage Works (DMRB 4.2)

HA 44 Design and Preparation of Contract Documents (DMRB 4.1.)

HD 41 Maintenance of Highway Geotechnical Assets (DMRB 4.1)

HA 71 The Effects of Highway Construction on Flood Plains (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 102 Spacing of Road Gullies (DMRB 4.2)

HA 103 Vegetated Drainage Systems for Highway Runoff (DMRB 4.2).

HA 104 Chamber Tops and Gully Tops for Road Drainage and Services: Installation and Maintenance (DMRB 4.2)

HA 105 Sumpless Gullies (DMRB 4.2)

HA 106 Drainage of Runoff from Natural Catchments (DMRB 4.2)

HA 107 Design of Outfall and Culvert Details (DMRB 4.2)

HA 113 Combined Channel and Pipe System for Surface Water Drainage (DMRB 4.2)

HA 118 Design of Soakaways (DMRB 4.2.)

HA 119 Grassed Surface Water Channels for Highway Runoff (DMRB 4.2.)

HA 216 Road Drainage and the Water Environment (DMRB 11.3.10)

HD 25 Foundations (DMRB 7.2)

HD 26 Pavement Design (DMRB 7.2)

HD 27 Pavement Construction Methods (DMRB 7.2)

HD 43 Drainage Data Management Systems for Highways (DMRB 4.2)

TA 57 Roadside Features (DMRB 6.3)

TA 80 Surface Drainage of Wide Carriageways (DMRB 4.2)

TD 9 Highway Link Design (DMRB 6.1)

TD 16 Geometric Design of Roundabouts (DMRB 6.2)

TD 25 Inspection and Maintenance of Traffic Signs on Motorway and All-Purpose Trunk Roads (DMRB 8.2)

4 BS 5931: 1980 'Machine laid in situ edge details for paved areas'

5 A Guide to Design Loadings for Buried Rigid Pipes. O C Young and M P O'Reilly. Transport and Road Research Laboratory. Department of Transport. HMSO, 1983

6 Materials Selection Manual for Sewers, Pumping Mains and Manholes. Foundation for Water Research, 1993

Manual of Sewer Condition Classification. WRc

Model Contract Document for Non Man Entry Sewer Inspection. WRc

7 Road Note 35. A guide for engineers to the design of storm sewer systems. Transport and Road Research Laboratory. Department of Transport. HMSO

8 Simplified Tables of External Loads on Buried Pipelines. O C Young, G Brennan and M P O'Reilly. Transport and Road Research Laboratory. Department of Transport, HMSO 1986

9 The Wallingford Procedure: Design and analysis of urban storm drainage. National Water Council, 1981

10 Long Term Monitoring of Pollution from Highway Runoff. F Moy, R W Crabtree, T Simmes. WRc report ref. UC 6037

11 BS EN 12899-1:2001 'Fixed, vertical road traffic signs Part 1: Fixed Signs'

10. ENQUIRIES

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

Chief Highway Engineer The Highways Agency 123 Buckingham Palace Road London SW1W 9HA	G CLARKE Chief Highway Engineer

Chief Road Engineer Transport Scotland Victoria Quay Edinburgh EH6 6QQ	J HOWISON Chief Road Engineer

Chief Highway Engineer Transport Wales Welsh Assembly Government Cathays Parks Cardiff CF10 3NQ	M J A PARKER Chief Highway Engineer Transport Wales

Director of Engineering The Department for Regional Development Roads Service Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	G W ALLISTER Director of Engineering