Design Manual for Roads and Bridges

Drainage
Design

CG 501
Design of highway drainage systems

(formerly HD 33/16, TA 80/99)

Revision 1

Summary
This document contains the over-arching requirements for drainage design on highways.

Application by Overseeing Organisations
Any specific requirements for Overseeing Organisations alternative or supplementary to those given in this document are given in National Application Annexes to this document.

Feedback and Enquiries
Users of this document are encouraged to raise any enquiries and/or provide feedback on the content and usage of this document to the dedicated Highways England team. The email address for all enquiries and feedback is: Standards_Enquiries@highwaysengland.co.uk

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Release notes

Version	Date	Details of amendments
1	Dec 2019	CG 501 revision 1 replaces CG 501 revision 0. This full document has been re-written to make it compliant with the new Highways England drafting rules. Revision 1 contains a minor revision to Table 8.6.4N3. The stated suspended solids % removal for dry/detention basins has been amended from 5% to 50% which was a typographical error. Clause 4.10 that referenced IAN 161 has been deleted as this was a cyclical reference and is not required.

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Foreword

Publishing information

This document is published by Highways England.

This document supersedes CG 501 revision 0.

Contractual and legal considerations

This document forms part of the works specification. It does not purport to include all the necessary provisions of a contract. Users are responsible for applying all appropriate documents applicable to their contract.

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Introduction

Background

This document sets out requirements and provides recommendations on the design of drainage for the UK motorway and all-purpose trunk roads. It describes the various alternative drainage solutions that are available, including their potential to control pollution and flooding, as well as detailed design factors to be taken into account.

Road drainage can be broadly split into two categories: surface and sub-surface drainage. Generally speaking, road surfacing materials are effectively impermeable, and rainfall which does not permeate the carriageway surface is shed towards the edges of the pavement and into surface water drainage systems. Surface water can also infiltrate into road foundations, earthworks or structures through any surface which is not completely impermeable, and as such sub-surface drainage is utilised to allow such water to drain through underlying pavement layers and away from the formation.

The types of drainage discussed in this standard are one element of road drainage. Other elements include:

1) outfalls and culverts - see CD 529 [Ref 2.N];
2) soakaways - see CD 530 [Ref 5.I];
3) reservoir pavements - see HD 221 [Ref 1.I];
4) sumpless gullies - see CD 527 [Ref 11.I];
5) chamber tops and gully tops - see HA 104 [Ref 2.I];
6) certification of drainage design - see CG 502 [Ref 19.N].

Surface drainage is achieved through collection of surface water runoff from the pavement (and potentially adjacent land) through formal (e.g. kerbs and gullies) or informal (over the edge) drainage, discharging into longitudinal surface channels or piped systems.

Sub-surface drainage is achieved by installation of longitudinal sub-surface drains situated in verges and/or central reserves at the low edges of road pavements. These drain the pavement layers and the pavement foundation (pavement and capping layers are contiguous with the side of the trench) and prevent ingress of water from verge areas adjacent to the pavement.

Drainage designs may utilise combined systems (where both surface water and sub-surface water are collected in the same pipe) or separate systems (where sub-surface water is collected in a separate drainage conduit from the one which is used for collection of surface water).

Assumptions made in the preparation of this document

The assumptions made in GG 101 [Ref 10.N] apply to this document.

Mutual Recognition

Where there is a requirement for compliance with any part of a "British Standard" or other technical specification, that requirement may be met by compliance with the Mutual Recognition clause in GG 101 [Ref 10.N].

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Abbreviations and symbols

Abbreviations

Abbreviation	Definition
EQS	Environmental Quality Standard
GWQS	Groundwater Quality Standard
MCHW	Manual of Contract Documents for Highways Works
NG	Notes for Guidance
PAHs	Polycyclic Aromatic Hydrocarbons
PCD	Pollution Control Device
PCS	Pollution control sign
SHW	Specification for Highways Works
SPZ	Source Protection Zone
SuDS	Sustainable Drainage Systems
VRS	Vehicle Restraint System
WFD	Water Framework Directive

Symbols

Symbol	Definition
FL	flow control
F	fin drain
GSWC	grassed surface water channel
NF	narrow filter drain
O	other pollution control mechanisms
S	spillage control
SW	surface water channel
V	vegetated systems
Y	yes
X	removal of pollutants likely to occur but insufficient evidence available to quote indicative treatment efficiency

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Terms and definitions

Terms

Term	Definition
Catchpit	Small chamber that road runoff passes through, incorporating sediment collection sump.
Combined channel and pipe drainage	Crushed stone/shingle filter medium over a perforated or porous carrier pipe. Drains both surface water from the pavement and groundwater to protect the pavement construction.
Combined kerb and drainage	Monolithic kerbs with internal drainage channel linked to openings in the kerb face.
Combined surface and sub-surface drain	System of filter drainage that comprises a perforated, porous or open jointed carrier pipe, bedded in granular material, in a trench that is then backfilled with a granular filter material of Type A, B or C as defined in Series 500 [Ref 12.N].
Crossfall	The slope on the road at right angles to the direction of travel.
Crown line	The line on the road where the crossfall changes.
Detention basin	Landscaped depression that is normally dry except during and following rainfall events, designed to temporarily store water to attenuate flows and, where vegetated, provide treatment of pollution.
Fin drain	A planar geocomposite arrangement designed to remove sub-surface moisture from beneath the pavement. NOTE: This can solely comprise a core surrounded by textile, or incorporate a pipe within the geotextile wrap.
First flush	The runoff from the first part of a rainfall event. NOTE: This usually is the most polluted runoff, especially when there is intense rainfall after long dry periods during which pollutants can accumulate on the road.
Flood plain	Any land with a 1 in 100 or greater annual probability of river flooding or a 1 in 200 or greater annual probability of sea flooding.
Flow path	The flow path is the route taken by rainfall runoff from the point at which it falls on the carriageway surface to the carriageway edge.
Flow path gradient	The overall net gradient produced from a combination of the longitudinal gradient and crossfall gradient (when changing from a superelevated carriageway to non-superelevated carriageway).
Grassed surface water channel	Grassed triangular or trapezoidal surface water channel that is installed at the pavement edge to collect and convey rainfall runoff from the road surface.

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Terms (continued)

Term	Definition
Groundwater	All water which is below the surface of the ground in the saturation zone (below the water table) and in direct contact with the ground or subsoil.
Handstop	Flat plate, fitted to a pair of guide slots on a headwall or chamber wall, which can be raised and lowered manually (rather than screw thread as per penstocks).
Hard shoulder	A nearside lane adjacent to a carriageway, for emergency use.
Hazardous substance	Substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern. NOTE: In accordance with the WFD 2000 [Ref 6.I].
High water table level	Maximum permitted level of the groundwater table beneath the road sub-formation.
Infiltration basin	Dry basin designed to promote infiltration of surface water into the ground.
Informal drain (over the edge)	An arrangement where surface water flows off the carriageway and across the verge to a drainage system, usually a ditch.
Kerb and gully drainage	System of drainage whereby surface water is directed by edge of pavement kerbs into gullies which are connected to a longitudinal carrier drain or pipe set within the road verge.
Linear drainage channel	A closed profile hydraulic conduit with slots or holes located in the top.
Narrow filter drain	An edge of pavement subsurface drain that comprises filter material and a carrier pipe, which can be wrapped in a geotextile.
Penstock	Flat plate, fitted to a pair of guide slots on a headwall or chamber wall, which can be raised and lowered using a screw thread operated by a wheel in order to control spillages.
Pollution	The direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which can be harmful to human health or the quality of aquatic ecosystems (or terrestrial ecosystems directly depending on aquatic ecosystems) which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment. NOTE: In accordance with the WFD 2000 [Ref 6.I].
Pervious asphalt	Asphalt material used to make pavement layers pervious with open voids to allow water to pass through.

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Terms (continued)

Term	Definition
Reasonably practicable	Something that is achievable without disproportionate level of complexity or having an impact on other design elements or construction, installation or maintenance of those elements. NOTE: Issues for consideration can include sewer capacity, maintenance responsibilities, capital and maintenance costs etc.
Reservoir pavement	Pavement where rainfall percolates through the pervious road surfacing, or runoff is diverted via gullies, edge drains and pipes into a porous sub-base material (reservoir). NOTE: Here, rain water accumulates before it slowly percolates into the soil subgrade or discharges through drains into the main surface water drainage system.
Retention pond	Pond that generally retains some water at all times. Can have permeable base or banks. Primarily designed to attenuate flows by accepting large inflows, but discharging slowly. Can also treat water by allowing suspended solids to settle out.
Roll-over lengths	Lengths of carriageway where the crossfall is varied for the provision/purpose of superelevation.
Sedimentation tank	A contained structure that allows suspended particles to settle out of water as it flows slowly through the tank, providing a degree of purification. NOTE: A layer of accumulated sludge collects at the base of the tank and needs periodic removal.
Soakaway	Sub-surface structure into which surface water is conveyed and which aids infiltration.
Source Protection Zone	Zones designated around public water supply abstractions and other sensitive receptors that show the risk of contamination from any activities that can cause pollution in the area.
Superelevated carriageway	Carriageway with a curved horizontal alignment where the crossfall slopes towards the inside of the bend.
Surface water body	Inland waters (except groundwater), transitional waters and coastal waters. NOTE: In accordance with the WFD 2000 [Ref 6.I].
Surface water channel (including channel blocks)	Triangular, trapezoidal or rectangular cross section channel, formed from asphalt or concrete, located near the edge of the carriageway, used to collect and convey surface water from the road.

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Terms (continued)

Term	Definition
Swale	A wide shallow grassed channel, normally located adjacent to a carriageway but often separated by a section of verge.
Wetland	A pond with a high proportion of shallow zones that promote the growth of bottom-rooted plants and which can be used for treatment of pollution.

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1. Scope

Aspects covered

1.1 The methods and design requirements in this document shall be applied where the design of new drainage is undertaken.

Implementation

1.2 This document shall be implemented forthwith on all schemes involving design of drainage on the Overseeing Organisations' motorway and all-purpose trunk roads according to the implementation requirements of GG 101 [Ref 10.N].

Use of GG 101

1.3 The requirements contained in GG 101 [Ref 10.N] shall be followed in respect of activities covered by this document.

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2. Design principles

Background

2.1 The design of surface and sub-surface drainage in UK motorway and all-purpose trunk roads shall:

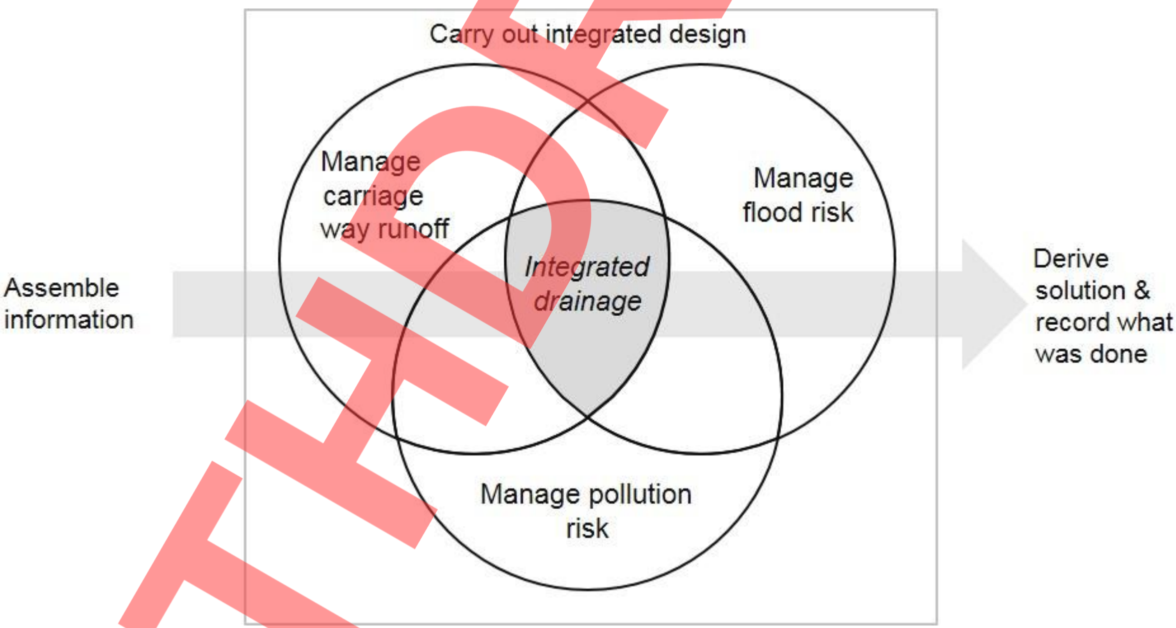
1) remove surface water from the carriageway as quickly as possible to provide safety and minimum nuisance to the road users;
2) maximise longevity of the pavement and its associated earthworks;
3) minimise the impact of the runoff on the receiving environment in terms of flood risk and water quality; and
4) manage water flows from earthworks and structures associated with the roads.

2.2 Designs must be undertaken in accordance with the Construction (Design and Management) Regulations S.I. 2015 No.51 [Ref 20.N].

2.3 Drainage design shall be integrated such that drainage of the road, water quality and flood risk simultaneously meet the requirements given in the remainder of the DMRB.

NOTE 1 The process of integrated drainage design is illustrated in Figure 2.3.N1.

Figure 2.3N1 Integrated design approach



NOTE 2 Requirements for the design of surface and sub-surface drainage are presented in:

1) *this document;*
2) *the reference documents listed in Table 3.4;*
3) *Series 500 [Ref 12.N];*
4) *Series NG 500 [Ref 13.N];*
5) *Section 1, Drainage of Volume 3 of the MCHW [Ref 11.N];*
6) *Section 1, Edge of Pavement Details of Volume 3 of the MCHW [Ref 11.N];*
7) *CD 523 [Ref 4.N] Determination of pipe roughness and assessment of sediment deposition to aid pipeline design;*
8) *CD 533 [Ref 3.N] Determination of pipe and bedding combinations for drainage works;*
9) *HD 217 [Ref 1.N] Alternative filter media and surface stabilisation techniques for combined surface and sub-surface drains;*

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10) *LA 113 [Ref 15.N] Road drainage and the water environment;*
11) *CD 521 [Ref 9.N] Hydraulic design of road edge surface water channels and outlets; and*
12) *HA 39 [Ref 7.N] Edge of Pavement Details.*

Destinations for road runoff

2.4 Road drainage shall be discharged to the following destinations in order of preference:

1) ground;
2) surface water body;
3) surface water sewer; and
4) combined sewer.

2.5 The decision process that shall be followed when determining the destination for road drainage is presented in Figure 2.5.

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Figure 2.5 Destination of road runoff - decision flowchart

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NOTE 1 *Groundwater quality standards (GWQSs) can vary over time and between the various Overseeing Organisations.*

NOTE 2 *The acceptability of different risks varies according to geographic location and is site specific.*

2.6 Road drainage shall only be discharged into lakes, ponds, canals or reservoirs where a site-specific risk assessment produced in compliance with LA 113 [Ref 15.N] demonstrates that this represents no or minimal risk to the lake, pond, canal or reservoir.

2.6.1 Discharge of road drainage to ground within a groundwater Source Protection Zone 1 (SPZ 1) should be avoided [Ref 12.I].

NOTE *Guidance on discharge of road drainage to ground within a SPZ 1 is given within LA 113 [Ref 15.N].*

2.6.2 Discharge of road drainage to ground within a groundwater Source Protection Zone 2 (SPZ 2) should be avoided [Ref 12.I] though the acceptance of such is likely to require less justification than within a SPZ 1.

2.7 Discharge of road drainage shall not be to a foul sewer.

2.8 Where the rate of surface water runoff is greater than the rate at which water is able to infiltrate into the ground, discharge to the ground shall be utilised to drain water within the capacity of the ground conditions.

2.9 Discharge to the ground shall not create an unacceptable risk of groundwater flooding, ground instability or groundwater contamination.

2.10 Where the rate of surface water runoff is greater than the rate at which water is able to infiltrate into the ground, the excess runoff shall be drained to surface water or sewer options in accordance with Figure 2.5.

2.10.1 When using the decision flowchart in Figure 2.5 the potential to use mitigation measures (such as flow attenuation or SuDS) should be evaluated.

General requirements

2.11 A document describing the technical basis of the drainage design shall be prepared and submitted to the Overseeing Organisation in accordance with CG 502 [Ref 19.N].

NOTE *Factors associated with baseline environment are site-specific and include catchment size, drained areas, runoff destination, space, topography, groundwater, soil permeability, existing drainage and sensitive receptors.*

2.12 The use of the decision flowchart in Figure 2.5, together with the justification for the outcomes of it, shall be recorded in the document describing the technical basis of the drainage design.

2.12.1 The drainage design should be carried out early in the design process for a project.

2.13 All drainage designs shall incorporate safety measures as required by CD 521 [Ref 9.N], HA 39 [Ref 7.N], HD 217 [Ref 1.N] and HA 103 [Ref 22.N].

NOTE *HA 103 [Ref 22.N] includes details of safety risk assessments and mitigation measures for open bodies of water.*

2.14 Assessment of effects of road drainage on the water environment shall be carried out in accordance with LA 113 [Ref 15.N].

2.15 All documentation shall be managed in accordance with CD 535 [Ref 5.N].

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3. Road drainage design selection

General

3.1 Detailed design of carriageway drainage shall identify the range of options and recommend the most suitable option based on site specific constraints.

NOTE Table 3.4 presents guidance on the suitability of different types of road drainage in different scenarios and references the documents that contain detailed design advice and standards.

3.2 The design process shall determine:

1) the appropriate destination of road runoff (see Figure 2.5);
2) the design storms to be used in the design of the drainage elements within the catchment under consideration;
3) the flows from the design storms at each drainage element within the catchment, incorporating the necessary allowances for climate change;
4) the hydraulic adequacy of each drainage element within the catchment;
5) where necessary, the structural loadings upon drainage conduits, and verification that each conduit can withstand the loading placed upon it;
6) the appropriate location and levels of associated outfalls and/or soakaways; and
7) where necessary, the incorporation of pollution and flood risk control measures.

3.3 Where excavation is required, the design of drainage systems shall include management of the excavated material to minimise waste and minimise risk to human health or the environment.

3.4 Justification shall be given for the system selected for drainage, based upon the requirements stated within this document.

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Table 3.4 Surface, combined and sub-surface drainage types

Drainage collector detail		Urban applications	Rural applications	Scenarios not suitable for	Reference documents for detailed design requirements
Surface drainage	Combined channel and pipe drains	1) not generally applicable.	1) high- speed roads; 2) embankments where verge space is limited.	1) areas subject to equestrian use; 2) in front of a vehicle restraint system (VRS) if the flow depth is greater than 150 mm; 3) within the working width behind VRS if the flow depth is greater than 200 mm.	CD 521 [Ref 9.N] HA 39 [Ref 7.N]
	Combined kerb and drainage system	1) areas of congested public utility services; 2) shallow outlets; 3) flat long gradients; 4) roundabouts.	1) flat long gradients where footways within highway verge; 2) roundabouts.	1) junction or stretch of road where maintenance would require road closure or complex traffic management requirements; 2) areas with leaf litter or where overhanging/ dense vegetation is present.	HA 39 [Ref 7.N] TA 57 [Ref 17.N]

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Table 3.4 Surface, combined and sub-surface drainage types (continued)

Drainage collector detail		Urban applications	Rural applications	Scenarios not suitable for	Reference documents for detailed design requirements
Surface drainage	Grassed surface water channels/swales	1) not generally applicable.	1) in verges for grassed surface water channels; 2) on gently sloping embankments for swales; 3) on areas where there is over the edge drainage.	1) on central reserve if located at the pavement edge; 2) where the height of an embankment exceeds the width of a proposed channel (due to the risk of percolation destabilising the embankment slope); 3) within a groundwater SPZ (unless unacceptable risk of groundwater pollution); 4) in front of a VRS if the flow depth is greater than 200 mm; 5) within the working width behind VRS if the flow depth is greater than 200 mm.	CD 521 [Ref 9.N]
	Informal drainage (over the edge)	1) not generally applicable.	1) in verges; 2) embankments (but only where there is an open ditch or watercourse at the base of the embankment).	1) locations where footways or segregated cycleways abut carriageways; 2) on structures; 3) embankments constructed of clayey or silty soil or of depth greater than 1.0 m and slope steeper than 1:3 (33%).	CD 521 [Ref 9.N] HA 39 [Ref 7.N]

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Table 3.4 Surface, combined and sub-surface drainage types (continued)

Drainage collector detail		Urban applications	Rural applications	Scenarios not suitable for	Reference documents for detailed design requirements
Surface drainage	Kerbs and gullies	1) general usage; 2) embankments.	1) footways within highway verge e.g. laybys; 2) roundabouts.	1) not recommended for rural roads unless footways are located within the verge, safety barriers or parapets are required, or continual surface and sub-surface drains are present; 2) where they can pose a hazard to pedestrian, cycle or equestrian crossings.	HA 39 [Ref 7.N] TA 57 [Ref 17.N] CD 526 [Ref 18.N]
	Linear drainage channels	1) car park areas; 2) adjacent to vertical concrete barriers; 3) nosings of interchanges.	1) nosings of interchanges.	1) in front of a VRS (when located in the verge or central reserve); 2) locations where frequent maintenance interventions are required; 3) areas subject to pedestrian and cyclist use (risk associated with slotted drains only); 4) areas with leaf litter or where overhanging/ dense vegetation is present; 5) areas subject to high sediment input.	HA 39 [Ref 7.N]

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Table 3.4 Surface, combined and sub-surface drainage types (continued)

Drainage collector detail		**Urban applications**	**Rural applications**	**Scenarios not suitable for**	**Reference documents for detailed design requirements**
Surface drainage	Surface water channels (including channel blocks)	1) not generally applicable.	1) high- speed roads; 2) embankments; 3) cuttings.	1) edge drains contiguous with hard shoulders, hardstrips or carriageways (channel blocks); 2) areas subject to equestrian use; 3) in front of a VRS if the flow depth is greater than 150 mm; 4) within the working width behind VRS if the flow depth is greater than 200 mm.	CD 521 [Ref 9.N] HA 39 [Ref 7.N]
Com-bined	Combined surface and sub-surface drains	1) not generally applicable.	1) along edge of cuttings or within central reserve where groundwater levels have the potential to interfere with operation of a surface water drainage system or there is limited verge width; 2) roads with long lengths of zero longitudinal gradient.	1) central reserves in order to reduce health and safety risks during maintenance; 2) in narrow verges subject to use by equestrians.	HA 39 [Ref 7.N] CD 533 [Ref 3.N] HD 217 [Ref 1.N]
Sub-surface drainage	Fin drain	1) not generally applicable.	1) edge of pavement where groundwater ingress is not expected to be large.	1) roads comprising rigid or flexible carriageways with over the edge drainage; 2) roads with free draining subgrade; 3) areas where significant groundwater ingress is expected.	HA 39 [Ref 7.N]
Sub-surface drainage	Narrow filter drain	1) not generally applicable.	1) edge of pavement where groundwater ingress is not expected to be large.	1) roads comprising rigid or flexible carriageways with over the edge drainage; 2) roads with free draining subgrade; 3) areas where significant groundwater ingress is expected.	HA 39 [Ref 7.N]

NOTE 1 *Additional details on the advantages and disadvantages of these drainage types are presented in Appendix A. Tables 3.5.1 and 3.5.2 provide details of edge of pavement and central reserve drainage design options.*

NOTE 2 *The general principle of highway drainage is that surface water and sub-surface water are kept separate as far as practically possible until the sub-surface water discharges to a chamber that connects to the carrier pipe. This is in order to prevent large amounts of water being introduced to the road pavement foundation (HA 44 91 [Ref 3.I]), however the use of combined drainage is preferable in certain circumstances (see Combined drainage and Table 3.4).*

3.5 Edge of pavement drains shall be included on all roads except the following, in accordance with HA 39 [Ref 7.N]:

1) roads with combined surface and sub-surface drains;
2) roads comprising rigid or flexible carriageways with over the edge drainage;
3) roads with free draining subgrade.

3.5.1 The decision processes presented in Table 3.5.1 may be used to determine the most appropriate edge of pavement drainage design.

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Table 3.5.1 Recommended design selections for verge-side edge drainage

Kerbs (with gullies) necessary because of: a) footway within highway verge b) urban conditions c) other site-specific considerations?								
	Yes - kerbs (with gullies) required			No - kerbs (with gullies) not required				
Location	**Road in cutting**		**Road on embankment**	**Road in cutting**		**Road on embankment**		
Constraints	Groundwater problems	No groundwater problems	-	Groundwater problems	No groundwater problems	No verge restrictions	Verge restrictions	Low embankment of granular material
Primary design solution	Combined surface and sub-surface drain	NF drain with long sealed carrier drain	NF or F drains with separate gully connections	Combined surface and sub-surface drain	SW channel with F or NF drain	SW channel with F or NF drain	SW channel with F or NF drain	Informal over the edge drain
Alternative design solution	GSWC	GSWC	-	GSWC	GSWC	-	-	GSWC

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NOTE *NF – narrow filter drain F – fin drain SW – surface water channel GSWC - grassed surface water channel.*

3.5.2 The decision processes presented in Table 3.5.2 may be used to determine the most appropriate central reserve drainage design.

Table 3.5.2 Recommended design selections for central reserve drainage

Location	Balanced carriageway		Super elevated carriageway	
Central reserve	Paved	Unpaved	Paved	Unpaved
Design solution	F or NF drain		SW channel and F or NF drain	
Alternative design solution	-	-	-	Combined surface and sub-surface drain

NOTE *NF – narrow filter drain F – fin drain SW – surface water channel.*

3.6 Where a pavement overlay is being installed over an existing pavement, the design of the overlay shall not compromise operation of existing pavement edge drainage.

3.7 The levels of gully grating and filter media on kerb and gully drains or combined surface and sub-surface drains shall be raised to match the new pavement level.

3.7.1 The edge of the overlay may be shaped to tie in with the top of surface water channels if it can be achieved without compromising the structural integrity of the pavement.

3.7.2 As an alternative to shaping the edge of the overlay, the existing drainage channel may be broken out and replaced at a higher level.

Surface water drainage design

3.8 Where surface water edge of pavement drainage is used it shall be designed in accordance with the requirements of this document, CD 521 [Ref 9.N], HA 39 [Ref 7.N], HD 217 [Ref 1.N] and LA 113 [Ref 15.N].

Kerb and gully drainage

3.9 Performance requirements specified in the design of a kerb and gully drainage system shall be set out in numbered contract specific Appendices 1/11, 5/1 and 5/5 to the Specification (MCHW Volume 2 [Ref 14.N]) taking into account any site-specific constraints.

3.10 Kerb and gully drainage systems located within the nosing sections of junction merge and diverge tapers shall be designed to withstand trafficking of the hard shoulder.

NOTE *Locations such as the nosing sections of junction merge and diverge tapers commonly have low points in cross-section due to the direction of crossfalls.*

3.11 Where kerb and gully drainage is designed in combination with fin drains, it shall not have an adverse effect on fin drain operation.

NOTE 1 *Functioning of kerb and gully systems is dependent upon the build-up of a flow of water in front of the kerb.*

NOTE 2 *Flows of water against the kerb face generally increase in the direction of longitudinal gradient until the flow is intercepted by a road gully.*

NOTE 3 *Build-up of widths of water flow, which have the potential to intrude into the hard shoulder, hardstrip or carriageway of the highway present a hazard to vehicles.*

3.12 Gully spacing shall be designed in accordance with CD 526 [Ref 18.N].

NOTE *Details of acceptable flow widths are presented in CD 526 [Ref 18.N].*

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3.12.1 For low embankments with toe ditches, gullies may discharge directly to the toe ditches via discrete outlets.

Combined drainage

3.13 Where combined surface and sub-surface drainage is used it shall be designed in accordance with the requirements of this document and HD 217 [Ref 1.N].

NOTE The requirements and advice on pipe and bedding combinations in combined surface and sub-surface drains is presented in CD 533 [Ref 3.N].

3.14 Surface treatment or stabilisation of combined surface and sub-surface drains shall be included in the design at locations where the risk of stone scatter occurring is greatest (refer to HD 217 [Ref 1.N]).

NOTE Potential risks associated with combined surface and sub-surface drains include surface failure of embankments and pavement failures.

3.14.1 To minimise surface water input at trench base level, the design of combined drainage for cuttings may include pipes with sealed joints and with perforations or slots laid uppermost.

3.14.2 Lining of trench bottoms with impermeable membranes up to pipe soffit level may be used to prevent infiltration of water from the drainage system into surrounding dry sub-soil or from polluting an underlying aquifer.

3.14.3 Separate design estimates for groundwater flow may not be needed when designing combined surface and sub-surface drainage for a cutting.

Sub-surface drainage design

3.15 Where sub-surface drainage is used it shall be designed in accordance with HA 39 [Ref 7.N].

3.16 The design of sub-surface drainage shall include shaping of the formation and sub-formation such that sub-surface water drains to longitudinal sub-surface drains.

3.17 Sub-surface drainage shall be designed to manage sub-surface water such that it does not reach the sub-base or capping layer of roads.

3.18 Where there is no capping, the design of fin drains and narrow filter drains shall include a depth to top of pipe greater than 50 mm below formation layer (as defined in Volume 1 of MCHW [Ref 11.N]).

3.19 Drains installed with a depth to top of pipe greater than 50 mm below formation layer shall be designed to maintain a 'high water table level' at a depth of 300 mm or greater below the road sub-formation level.

NOTE High groundwater levels have the potential to interfere with the operation of a surface water drainage systems.

3.19.1 To achieve the 'high water table level' or lower, fin or narrow filter drains may be installed at a greater depth than the minimum shown in Volume 3 of MCHW [Ref 11.N].

3.20 The design of sub-surface drainage shall not contain any low spots where water can accumulate.

3.20.1 Use of 100 mm diameter pipes within narrow filter drains, rather than pipes of smaller diameter, may reduce future maintenance costs.

3.21 The sub-base shall be drained unless the underlying materials (capping or subgrade) are more permeable than the sub-base, and the water table is never within 300 mm of the underside of the foundation (in accordance with HD 25 [Ref 4.I]).

Embankments and cuttings

3.22 Sub-surface drainage in cuttings shall lower groundwater to a depth such that it does not have the potential to interfere with the operation of a surface water drainage system (in accordance with HD 217 [Ref 1.N]).

3.22.1 Circumstances in which sub-surface drainage may be omitted are described in HA 39 [Ref 7.N].

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Groundwater

3.23 Sub-surface drainage shall function regardless of variations in groundwater level.

NOTE 1 Water moves partly by gravity and partly by capillary action, and these movements are susceptible to control by subsoil drainage.

NOTE 2 Groundwater is subject to seasonal variations consequential to rainfall conditions, geology and soil permeability.

3.23.1 Ground investigations undertaken to inform a drainage design should provide groundwater level data representative of worst case conditions.

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4. Climate change

Climate change allowances

4.1 All scheme designs shall incorporate assessment of and mitigation against the potential impacts of climate change.

4.2 Drainage designs shall be developed on the basis that all new road drainage has a minimum design lifetime of 60 years, unless otherwise instructed by the Overseeing Organisation.

4.3 All scheme designs shall include the latest climate change allowances in accordance with relevant national policy.

4.4 For the design of carriageway drainage, calculation of a 20 % uplift in peak rainfall intensity together with a sensitivity test to 40 % uplift in peak rainfall intensity shall be undertaken and documented within the report describing the technical basis of the drainage design.

NOTE The difference between the 20 % and 40 % scenarios enables understanding of the range of impact between climate change risk scenarios.

4.5 The 20 % increase in peak rainfall intensity shall be the minimum increase accommodated by the carriageway drainage design.

4.6 Use of an increase in peak rainfall intensity of greater than 20 % in carriageway drainage design shall be subject to approval by the Overseeing Organisation.

4.7 Justification for the value of peak rainfall intensity chosen for the carriageway drainage design shall be given within the report describing the technical basis of the drainage design.

4.8 All scheme designs shall include assessment and minimisation of flood risk in compliance with the requirements set out in LA 113 [Ref 15.N].

NOTE This document addresses how the effects of climate change are dealt with as part of drainage design only.

4.9 In schemes that use existing outfalls current discharge rates shall not be exceeded.

4.10 All pavement edge drainage for collection of surface runoff plus the carrier pipes/conduits that convey that runoff shall be designed based on the rainfall experienced by the catchment in which the road is located.

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5. Storm flows and flood risk

5.1 For road runoff within drainage systems the following overall design criteria shall apply:

1) 1 in 1 year – no surcharge of the drainage system; and
2) 1 in 5 years – no flooding from the drainage system.

NOTE *This requirement applies to all types of road drainage.*

5.2 The requirements for various types of drainage, relating to 1 in 1 and 1 in 5 year storm events, as outlined in Table 5.2 shall be adhered to.

Table 5.2 Storm event requirements

Location/ drainage type	1 in 1 year storm requirements	1 in 5 year storm requirements
Carrier drains	Drain to accommodate flows in-bore without surcharge over the crown of the pipe.	Flows not to cause chamber surcharge levels to rise above the soffit of the chamber cover.
Combined surface and sub-surface drains	Drain to accommodate flows in-bore without surcharge.	Flows not to cause chamber surcharge levels to rise above the formation level, or sub-formation level where a capping layer is present.
Surface water channels	Flows to be contained within the channel. No surcharge to take place.	Surcharge not to encroach into the running lane.
Verges	Surcharges for storms up to 1 in 5 year return period limited to a width of 1.5 m in the case of hard shoulder and 1.0 m in the case of hardstrip.	
Central reserve	Surcharges for storms up to 1 in 5 year return period not to encroach the carriageway. Flooding within non-pavement width of the central reserve permissible providing there is safeguard against flows from the surcharged channel overtopping the central reserve and flowing into the opposing carriageway.	

NOTE *For combined surface and sub-surface drains, 1 in 5 year storm requirements are based on the assumption that pipes are sealed and that flow between pipes and filter material does not take place.*

5.3 All drainage systems shall be designed so that highway surface water flooding does not extend beyond the highway boundary up to the 1 in 100 year rainfall event including an allowance for climate change.

5.3.1 The risks associated with events that exceed the capacity of the drainage system should be evaluated and documented within the report describing the technical basis of the drainage design.

5.3.2 The design of the site and the drainage system should cope with events that exceed the design capacity of the system, so that excess water can be safely stored on or conveyed from the site without adverse impacts.

NOTE *The level of events that need assessment depends upon site-specific conditions and the consequences of such an event occurring. For further advice see CIRIA C753 [Ref 13.I] and CIRIA C688 [Ref 8.I].*

5.3.3 Analytical tools (e.g. software) utilised to calculate runoff flows from roads should model particular storm intensities and permit analysis of the system under surcharged conditions.

5.4 The assessment of flood risk both to a project and resulting from a scheme shall be undertaken in accordance with LA 113 [Ref 15.N].

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6. Drainage from adjacent land

Drainage from adjacent land

6.1 Assessment of existing land drainage and runoff from catchments adjacent to the road pavement shall be included in the design of highway drainage in accordance with HA 106 [Ref 6.N].

NOTE *Runoff can be derived from land both within the overall highways boundary or external to it.*

New and existing connections

6.2 In order to ensure the integrity of road drainage systems, no new runoff that arises due to any change of use of land within the surface water catchment of the road shall be accepted into the drainage systems of motorways and all-purpose trunk roads.

6.3 No new connections from drainage systems of third party developments shall be permitted to enter the drainage systems of motorways and all-purpose trunk roads (DfT Circular 02/2013 [Ref 21.N]).

6.3.1 Where there is an existing connection of external drainage to the road drainage, either historical or by agreement, the right of connection may be permitted by the Overseeing Organisation to continue provided that the input from the contributing catchment to the connection remains unaltered (DfT Circular 02/2013 [Ref 21.N]).

6.3.2 Existing surface water flows from Local Authority side roads may continue where there is no alternative outfall, subject to agreement by the Overseeing Organisation.

Management of land drainage

6.4 Where it is not possible to avoid surface water and sub-surface water from adjoining land flowing towards a road, that land drainage shall be managed in accordance with HA 106 [Ref 6.N].

6.4.1 Selection of the most appropriate edge of pavement drainage design may be undertaken using the decision process presented in Table 3.4.

6.4.2 During the choice of drainage system the potential for contaminated ground or groundwater to exist at or adjacent to the road should be assessed.

NOTE *Installation of drainage early in the construction process allows management of land drainage during construction.*

6.5 The potential effect of proposed drainage ditches on embankment or cutting slope stability shall be subject to geotechnical assessment.

6.5.1 In rural areas, ditches may be used to provide a more effective and efficient option than formal drains.

NOTE 1 *Offsetting of toe ditches from the base of slopes can aid maintenance of slope stability.*

NOTE 2 *Assessment of slope stability early in the design process can assist in identification of land acquisition requirements for the project.*

NOTE 3 *Offsetting of toe ditches could also have implications for the:*

1) choice of drainage solution;

2) management of adjacent land; and

3) landscape design.

6.6 Where a road crosses an existing watercourse or ditch, the drainage design shall fulfil the requirements of LA 113 [Ref 15.N], HA 106 [Ref 6.N] and CD 529 [Ref 2.N].

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7. Road geometry

7.1 The design of road geometry shall enable the drainage of surface water runoff for any given length of carriageway.

7.2 The design of road geometry shall allow the discharge of subgrade drainage at levels above the design flood level for any given length of carriageway.

NOTE The need to provide appropriate drainage can be a factor in the design height of embankments and design depth of cuttings.

7.2.1 A coordinated analysis of the horizontal and vertical alignments with reference to surface water drainage should be carried out before alignments are fixed.

7.3 The construction tolerances permissible for road levels shall be assessed when producing a road surface design that can shed water as effectively as possible.

Drainage of superelevated carriageways

7.4 Superelevated carriageways shall be designed to adequately drain water from the carriageway.

7.4.1 A flow path gradient of at least 0.5 % may be used to facilitate drainage from superelevated carriageways (see CD 109 [Ref 10.I]).

NOTE 1 Where superelevation is applied or removed the crossfall of a carriageway can be insufficient for drainage purposes without assistance from the longitudinal gradient of the road.

NOTE 2 The flow path gradient of super elevated carriageways includes the effects of the application of superelevation acting against the gradient where superelevation is applied to a downhill gradient or removed on an uphill gradient.

7.4.2 The superelevation area may be moved to a different location by revision of the horizontal alignment, increasing the variation in grade of the edge profile or applying a rolling crown (CD 109 [Ref 10.I]).

NOTE Further advice on shedding of water from superelevated carriageways is provided in CD 109 [Ref 10.I] and CD 116 [Ref 9.I].

Drainage of wide carriageways

Drainage flow paths

7.5 Wide carriageways shall be designed to adequately drain water from the carriageway.

7.5.1 The combinations of longitudinal gradient and crossfall that fall below the curves given in Figure 7.5.1 should be avoided.

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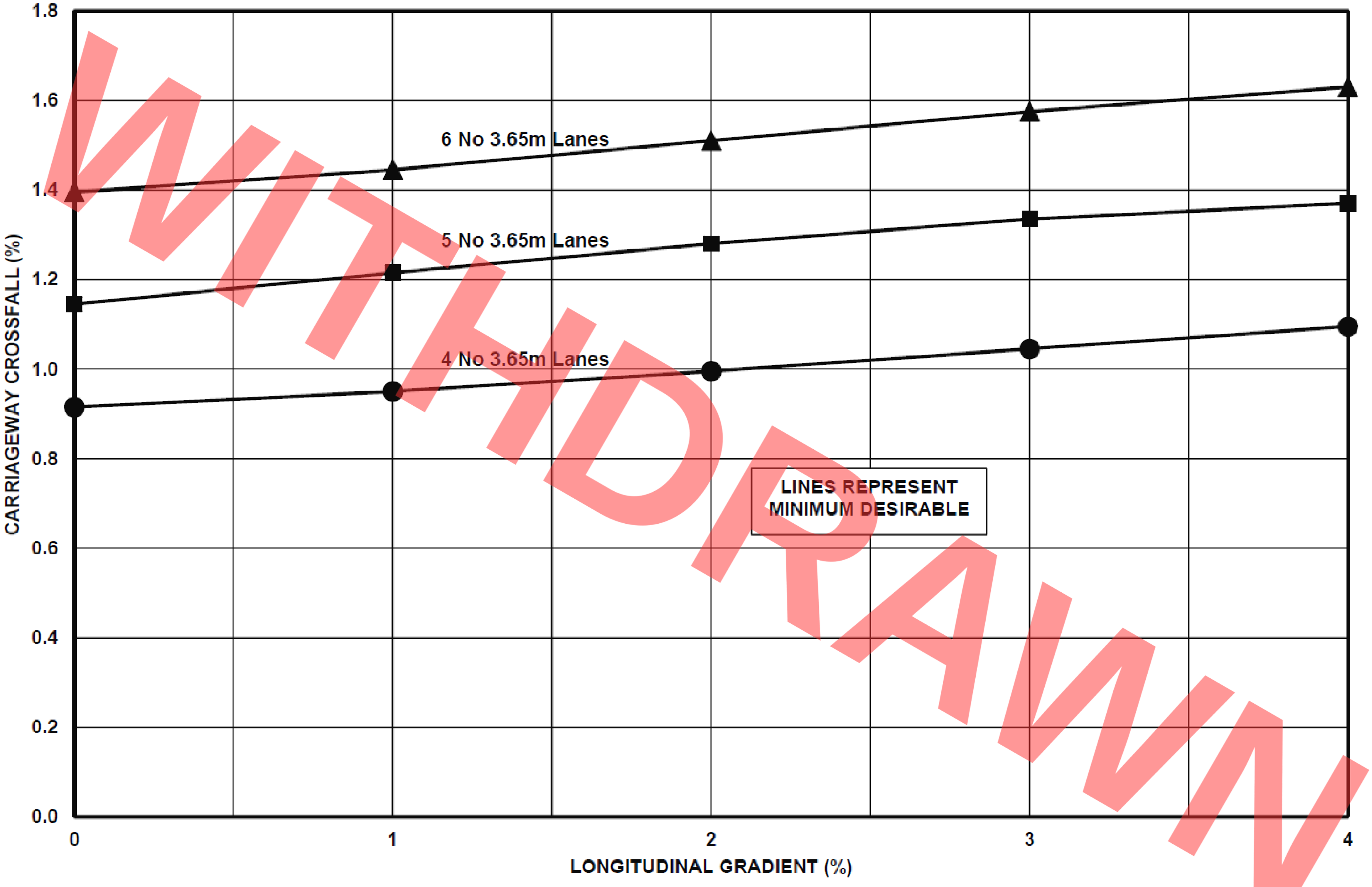
Figure 7.5.1 Effect of geometric design on drainage



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7.5.2 For lengths of carriageway with varying width and geometry, contoured plans of the carriageway surface should be generated in order to calculate local flow path lengths and gradients.

7.5.3 Flow path lengths and gradients may be checked by referring to Figures 7.5.3N2a and 7.5.3N2b.

NOTE 1 Flow path lengths can increase rapidly at low crossfalls.

NOTE 2 Roll-over lengths between superelevation are areas where low crossfalls occur and flow path lengths can be long.

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Figure 7.5.3N2a Flow path lengths (4 no. 3.65 m lanes)

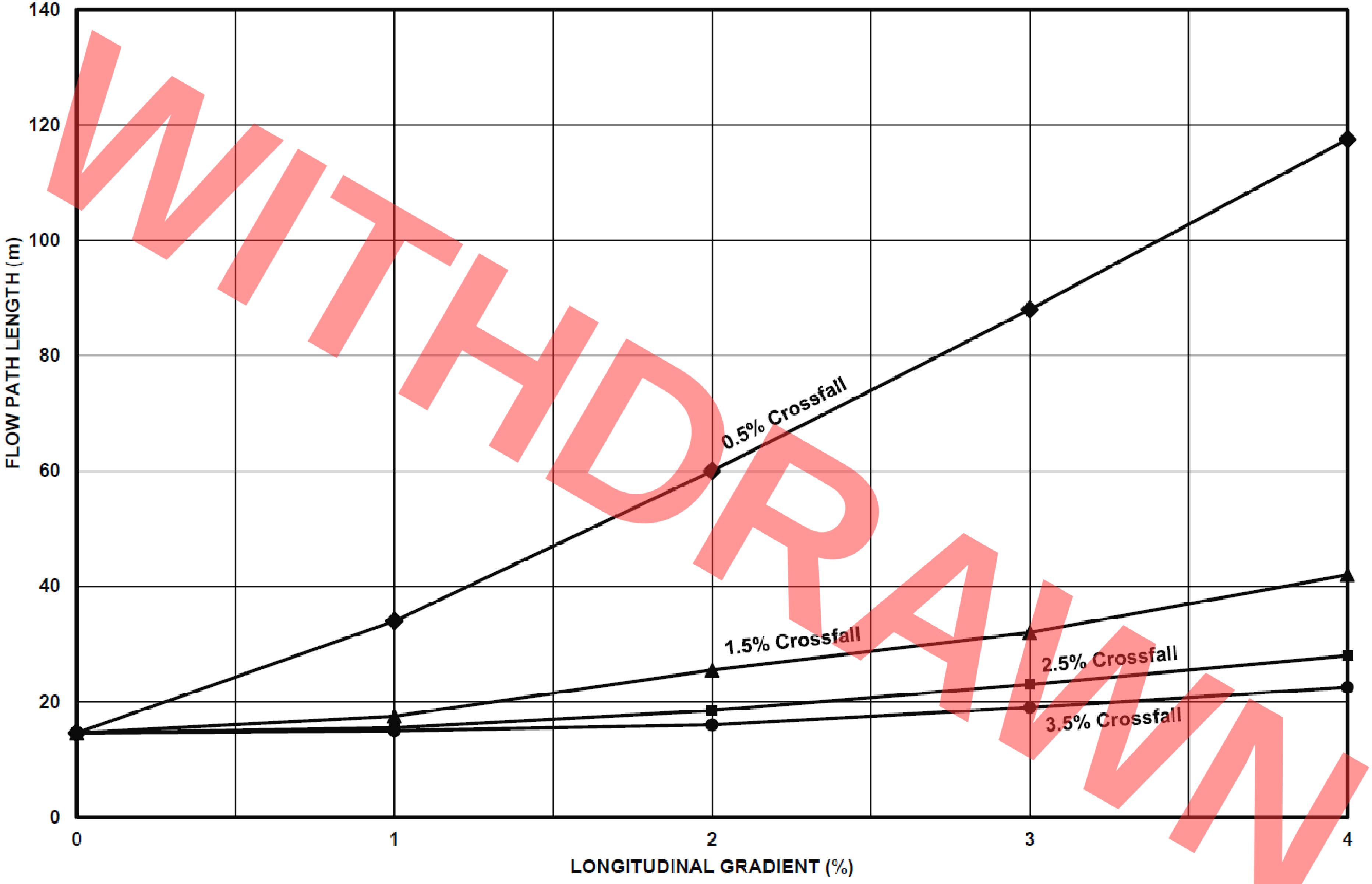

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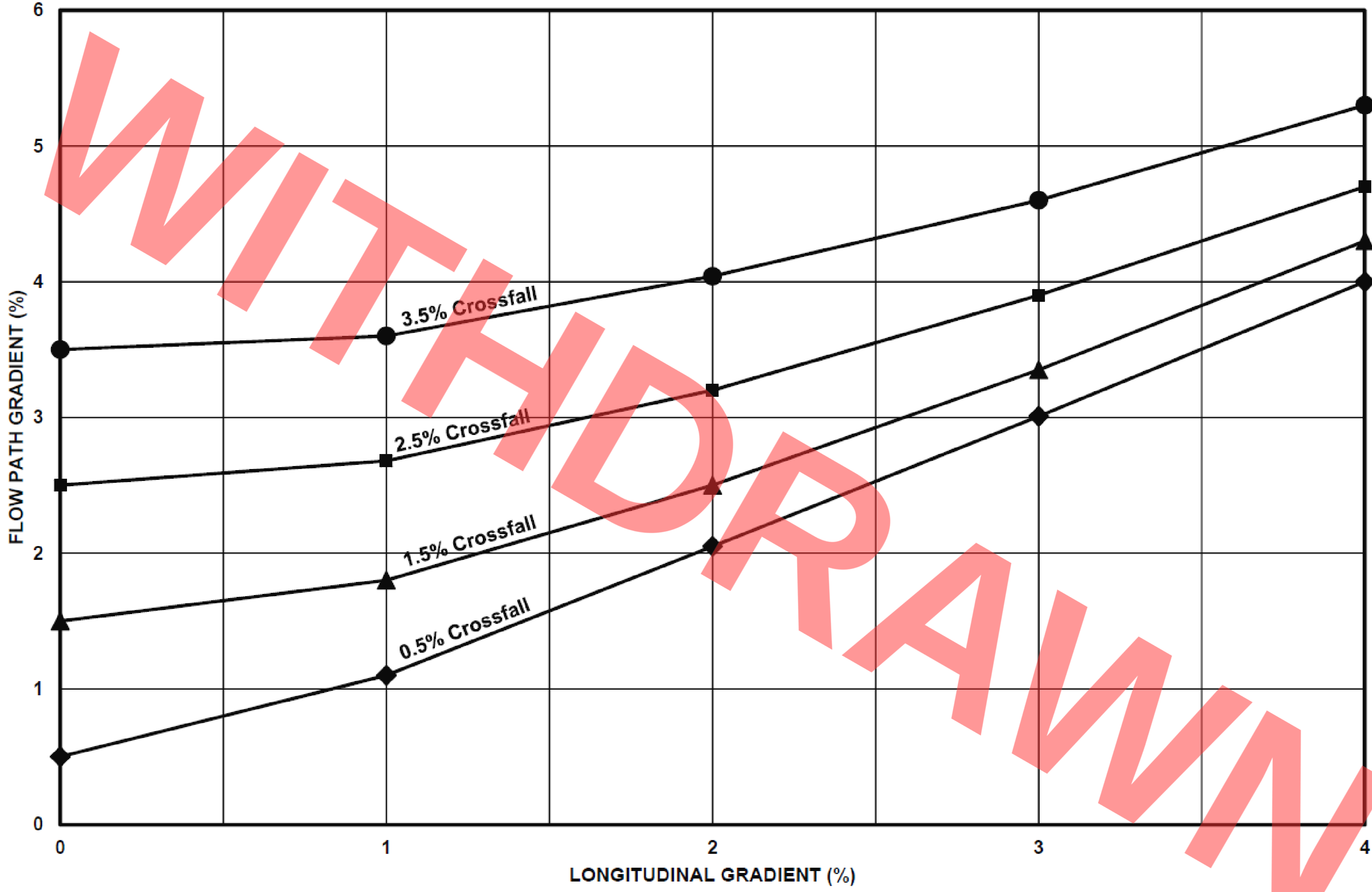
Figure 7.5.3N2b Flow path gradients



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7.5.4 For lengths of carriageway with consistent geometry the combinations of localised flow path lengths and gradients shown below the curve on Figure 7.5.4 should be avoided.

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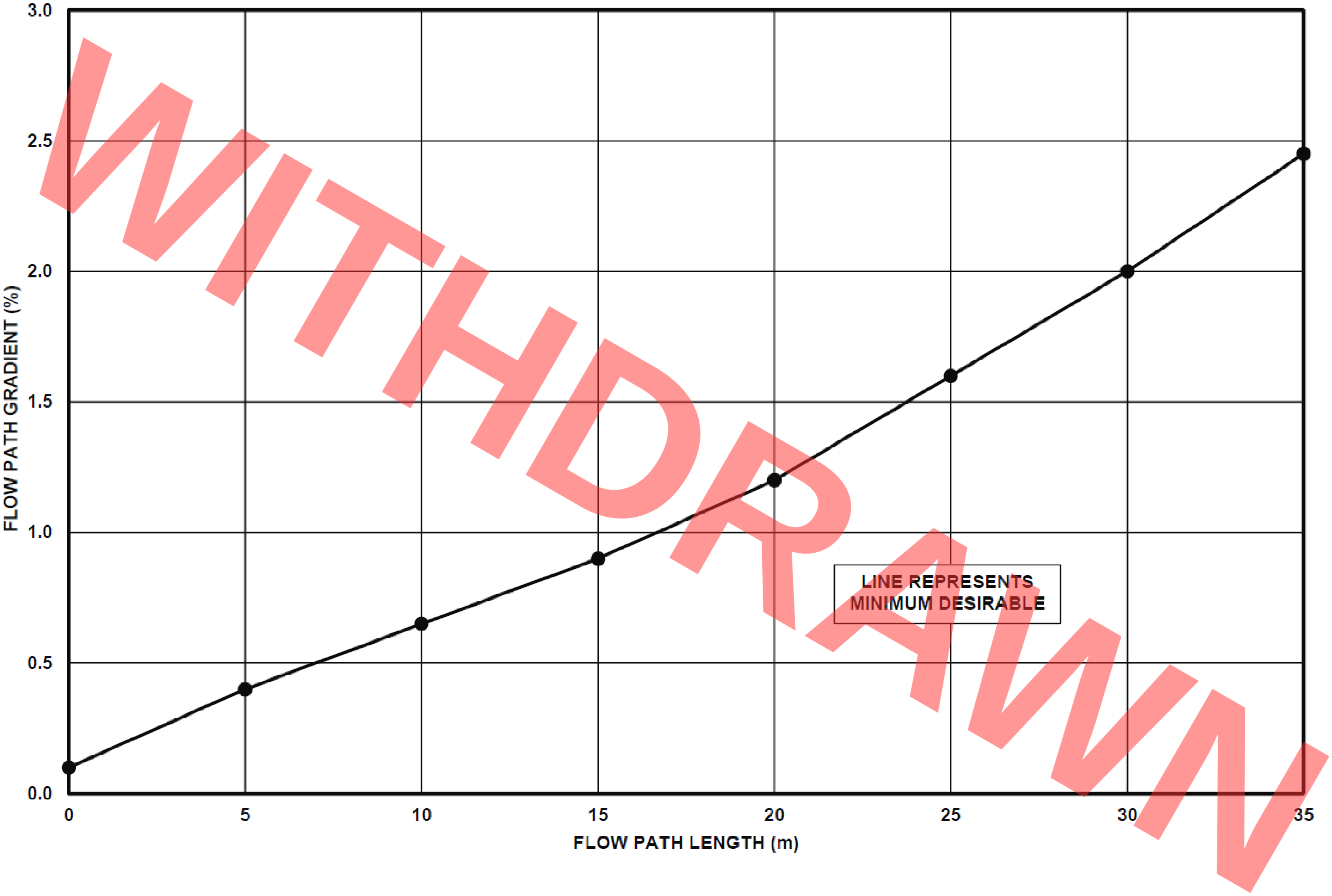
Figure 7.5.4 Effect of flow path length and flow path geometry on drainage



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Effect of carriageway edge markings

7.6 Continuous carriageway edge markings shall not exceed a thickness of 3 mm at the drainage exits to superelevation roll-over areas with sections having a crossfall less than 0.67 % (1 in 150).

NOTE 1 Carriageway surface drainage has the potential to be affected by continuous edge markings, particularly where raised rib markings are used.

NOTE 2 A continuous carriageway edge marking thickness of less than 3 mm allows water to drain over the line during storms.

7.7 Where the longitudinal gradient on any section of road is less than 0.67 % (1 in 150) 400 mm wide gaps shall be provided at 5 m centres in raised rib markings to minimise the risk of ice formation.

7.8 Where renewal of markings is being undertaken, existing lines shall be removed at the drainage exit to a superelevation roll-over area, where the longitudinal gradient is less than 0.67 % (1 in 150).

Crossfalls

7.9 Crossfalls shall be incorporated into the design to adequately drain water from the carriageway.

7.9.1 Where carriageway crown lines are used, crossfalls should be reduced from the standard 2.5 % (1 in 40) to 2 % (1 in 50) for one lane width either side of the crown, to limit the change of angle to 4 % (1 in 25).

NOTE 1 In CD 109 [Ref 10.I] guidance is given on how to assess both the drainage and appearance of the road when applying superelevation.

NOTE 2 Crown lines are more easily introduced between hard shoulders and superelevated carriageways and at merges and diverges where lane gains and lane drops occur.

NOTE 3 Rolling crowns (crowns that run diagonally) can be applied where surface drainage cannot otherwise be achieved.

7.9.2 Carriageway crossfalls may be increased from the standard 2.5 % (1 in 40) to 2.85 % (1 in 35) on lengths of carriageway that are straight or have radii well in excess of those requiring elimination of adverse camber.

NOTE Applying an increased crossfall on the additional nearside lanes of a widened carriageway does not significantly reduce the depth of water at the edge of the carriageway but can increase the capacity of the road edge channel where kerbs are used.

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8. Pollution and flow control design

Principles of pollution and flow control

8.1 Assessment of effects of road drainage on the water environment shall be carried out in accordance with LA 113 [Ref 15.N].

8.2 LA 113 [Ref 15.N] shall be used to identify the need for pollution and flow control measures within a drainage design.

8.3 Pollution control measures shall be designed in compliance with LA 113 [Ref 15.N].

NOTE A number of the pollution control measures discussed within this document also provide a degree of flow control.

8.3.1 Pollution control measures should be designed to treat the 'first flush'.

NOTE Discharges from short intense storms with long antecedent dry periods pose a higher pollution threat than discharges from longer rainfall events, which provide higher dilution.

8.3.2 A degree of bypass may be acceptable for the larger storm events, where runoff volumes can be higher and therefore there can be a greater degree of dilution.

NOTE Further information on design of pollution control measures in drainage is published in CIRIA C753 [Ref 13.I] and the DMRB documents referenced in Table 8.6.4N3.

8.4 Where the design of pollution control measures includes infiltration into ground, the risk to groundwater shall be assessed and mitigation measures, where that assessment identifies the need, implemented in accordance with LA 113 [Ref 15.N].

8.5 The design of pollution control measures shall include safe means of access for operation (where relevant), emergency response and maintenance.

8.5.1 Pollution control measures should be located above the level of the flood plain wherever possible.

NOTE Storm water inundation can compromise the operation of pollution control devices.

Selection of pollution and flow control measures

8.6 The selection and design of pollution and flow control measures shall follow the process presented below:

1) complete assessment in accordance with LA 113 [Ref 15.N];
2) if mitigation is required, identify viable options/combinations of measures, taking account of:
   a) road drainage hierarchy in this document;
   b) site constraints;
   c) storm flow and flood risk requirements;
   d) climate change allowances; and
   e) road geometry.
3) review short list of options against construction and maintenance requirements;
4) confirm measures fulfil mitigation requirements identified from LA 113 [Ref 15.N] assessment;
5) obtain approval for mitigation measures from Overseeing Organisation or relevant statutory consultation body; and
6) incorporate mitigation measures into overall drainage design.

8.6.1 Pollution control measures may be used to intercept pollution close to its source, treat it, manage sediment mobilisation or reduce the risks from spillages.

NOTE 1 The selection and design of systems depends on the pollution load, the risk of spillage or flood and the site conditions, particularly if protected habitats, species or sites can be affected.

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NOTE 2 Guidance on the design of pipelines for reduced sediment deposition is contained in CD 523 [Ref 4.N].

NOTE 3 Measures to control flooding generally include limiting (attenuating) peak outflows and providing an appropriate volume of water storage in the system to accommodate large or critical storm events.

8.6.2 Drainage designs for roads may include the following general categories of pollution control measures:

1) vegetated systems;
2) spillage control;
3) flow control; and
4) other pollution control mechanisms such as removal/separation of sediments or oils.

8.6.3 Where site conditions allow the use of vegetated systems their use should be prioritised over other forms of treatment.

NOTE Further detail on the design of vegetated systems can be found in HA 103 [Ref 22.N].

8.6.4 Where verge space restricts the use of vegetated systems, the use of conventional drainage systems, either independently or in combination with vegetated systems should be reviewed.

NOTE 1 Table 8.6.4N3 presents potential treatment efficiencies for the various pollution control measure types for different contaminants.

NOTE 2 Types of treatment other than those listed in Table 8.6.4N3 are available.

NOTE 3 The advantages and disadvantages of a selection of pollution control measures are presented in Appendix B.

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Table 8.6.4N3 Pollution and flow control measures options

Name of measure	Category of measure				Design standard reference documents	Indicative treatment efficiencies			Optimum spillage risk reduction factor R_F
	Vegetated systems	Spillage control	Flow control	Other pollution control mechanisms		Suspended solids (% removal)	Dissolved copper (% removal)	Dissolved zinc (% removal)	
Baffles		Y	Y			0	0	0	
Combined kerb and drainage blocks			Y			0	0	0	
Combined kerb and gully		Y		Y - sediment removal		X	X	X	
Combined surface and sub-surface drains/filter drain		Y	Y	Y - pollutant removal	HD 217 [Ref 1.N]	60	0	45	0.6
Ditch (vegetated)	Y	Y - lined	Y - lined/ unlined	Y - sediment/ pollutant removal (unlined)	HA 103 [Ref 22.N] (vegetated)	25	15	15	0.7
Dry/detention basin	Y		Y	Y - pollutant removal	HA 103 [Ref 22.N]	50	0	0	0.6
Infiltration basin/soakaway	Y		Y	Y - pollutant removal	HA 103 [Ref 22.N] CD 530 [Ref 5.I]	Infiltration of water facilitates the removal of dissolved metals and solids.			0.6 (infiltration basin)
Notched weir		Y	Y			0	0	0	0.6
Penstock/valve		Y	Y			0	0	0	0.4
Piped systems			Y			0	0	0	
Ponds	Y		Y	Y - pollutant removal	HA 103 [Ref 22.N]	60	40	30	0.5
Reservoir pavement/pervious asphalt			Y	Y - sediment removal	HD 221 [Ref 1.I]	50	0	0	
Sedimentation tank		Y		Y - sediment removal		40	0	0	

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Table 8.6.4N3 Pollution and flow control measures options (continued)

Name of measure	Category of measure				Design standard reference documents	Indicative treatment efficiencies			Optimum spillage risk reduction factor R_F
	Vegetated systems	Spillage control	Flow control	Other pollution control mechanisms		Suspended solids (% removal)	Dissolved copper (% removal)	Dissolved zinc (% removal)	
Sediment trap (catchpit)				Y - sediment removal		X	X	X	0.6
Surface water channel		Y			CD 521 [Ref 9.N]	X	X	X	
Swale/grassed channel	Y	Y	Y	Y - pollutant removal	HA 103 [Ref 22.N] CD 521 [Ref 9.N]	80	50	50	0.6
Vortex chamber			Y			0	0	0	
Vortex grit separator		Y		Y - sediment/ pollutant removal	HD 220 [Ref 14.I]	40	0	15	
Wetland (surface flow)	Y		Y	Y - pollutant removal	HA 103 [Ref 22.N]	60	30	50	0.5

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NOTE 4 *Y - yes, X - removal of pollutants likely to occur but insufficient evidence available to quote indicative treatment efficiency.*

NOTE 5 *Sedimentation tanks are not reliable for the removal of dissolved copper and zinc, nor vortex grit separators for the removal of copper.*

NOTE 6 *A high proportion of highway pollutants are found to be adsorbed to the fine silt fraction of the suspended solids. By collecting, filtering and treating the fine sediment which is subsequently removed, the system deals with a significant part of the runoff pollution.*

NOTE 7 *The spillage risk reduction factors in Table 8.6.4N3 represent what is considered achievable. Actual risk reduction factors are site-specific and potentially higher (representing a lower risk reduction) depending on factors such as size of treatment system and retention time.*

8.7 Oil separators shall not be used.

8.7.1 Existing oil separators should be replaced by an alternative solution for mitigating the potential impacts of road runoff.

NOTE 1 *Oil separators are designed to mitigate oils and cannot be relied upon to treat suspended solids or dissolved metals.*

NOTE 2 *Oil separators require regular maintenance to function effectively.*

Signage of pollution control devices

8.8 Signs marking the location of pollution control devices are labelled as PCD (pollution control device) and shall be designed in accordance with BS EN 12899-1 2007 [Ref 8.N].

8.9 The faces of pollution control signs (PCS) used shall be one of the options shown in Figure 8.9 and meet the requirements shown in Table 8.9.

Figure 8.9 Pollution control sign design options

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Table 8.9 Required attributes of pollution control signs

Attribute	PCD1	PCD2	PCD3	PCD4
Legend	white	white	white	white
Background	light green	light green	light green	light green
Border	yellow	yellow	yellow	yellow
Font	transport medium	transport medium	transport medium	transport medium
Material	class 1	class 1	class 1	class 1
X-height (mm)	50	50	50	50
Width (mm)	320	320	320	320
Height (mm)	190	310	410	410
Area (m^2)	0.06	0.1	0.13	0.13

NOTE 1 Class 1 - material that is retro-reflective Class 1 material in accordance with BS EN 1463 [Ref 16.N].

NOTE 2 Illumination of pollution control signs is not required.

8.10 The location of PCSs other than at the edge of the carriageway shall not be permitted without approval of the Overseeing Organisation.

8.11 PCSs shall be visible from the running lanes of the carriageway.

8.11.1 The location of PCSs should be at least 600 mm from the edge of a single carriageway and 1500 mm from the edge of high-speed dual carriageway or motorway.

8.11.2 The mounting height of PCSs should be at least 900 mm above the highest point of the carriageway immediately adjacent to the sign.

8.11.3 The mounting height of PCSs may be increased up to 1500 mm where excessive spray is likely to occur around the sign.

8.11.4 PCSs should specify the distance and direction to the device.

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9. Normative references

The following documents, in whole or in part, are normative references for this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Ref 1.N	Highways England. HD 217, 'Alternative filter media and surface stabilisation techniques for combined surface and sub-surface drains. '
Ref 2.N	Highways England. CD 529, 'Design of outfall and culvert details'
Ref 3.N	Highways England. CD 533, 'Determination of pipe and bedding combinations for drainage works'
Ref 4.N	Highways England. CD 523, 'Determination of pipe roughness and assessment of sediment deposition to aid pipeline design'
Ref 5.N	Highways England. CD 535, 'Drainage asset data and risk management'
Ref 6.N	Highways England. HA 106, 'Drainage of Runoff from Natural Catchments'
Ref 7.N	Highways England. HA 39, 'Edge of Pavement Details'
Ref 8.N	BSI. BS EN 12899-1, 'Fixed, vertical road traffic signs. Fixed signs' , 2007
Ref 9.N	Highways England. CD 521, 'Hydraulic design of road edge surface water channels and outlets'
Ref 10.N	Highways England. GG 101, 'Introduction to the Design Manual for Roads and Bridges'
Ref 11.N	Highways England. MCHW, 'Manual of Contract Documents for Highway Works'
Ref 12.N	Highways England. Series 500, 'Manual of Contract Documents for Highway Works, Volume 1 Specification for Highway Works. Series 500 Drainage and service ducts.'
Ref 13.N	Highways England. Series NG 500, 'Manual of Contract Documents for Highway Works, Volume 2 Notes for Guidance on the Specification for Highway Works. - Drainage and Service Ducts'
Ref 14.N	Highways England. MCHW Volume 2, 'Notes for Guidance on the Specification for Highway Works'
Ref 15.N	Highways England. LA 113, 'Road drainage and the water environment'
Ref 16.N	BSI. BS EN 1463, 'Road marking materials. Retroreflecting road studs'
Ref 17.N	Highways England. TA 57, 'Roadside Features'
Ref 18.N	Highways England. CD 526 , 'Spacing of road gullies'
Ref 19.N	Highways England. CG 502, 'The certification of drainage design '
Ref 20.N	The Stationery Office. S.I. 2015 No.51, 'The Construction (Design and Management) Regulations 2015'
Ref 21.N	Department for Transport. DfT Circular 02/2013 , 'The strategic road network and the delivery of sustainable development'
Ref 22.N	Highways England. HA 103, 'Vegetative Treatment Systems for Highway Runoff'

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10. Informative references

The following documents are informative references for this document and provide supporting information.

Ref 1.I	Highways England. HD 221, ' Reservoir Pavements for Drainage Attenuation'
Ref 2.I	Highways England. HA 104, 'Chamber Tops and Gully Tops for Road Drainage and Services: Installation and Maintenance'
Ref 3.I	Highways England. HA 44, 'Design and Preparation of Contract Documents' , 91
Ref 4.I	Highways England. HD 25, 'Design Guidance for Road Pavement Foundations'
Ref 5.I	Highways England. CD 530, 'Design of soakaways'
Ref 6.I	WFD 2000, 'Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy'
Ref 7.I	'Environmental Permitting (England and Wales) Regulations 2016 (SI 2016 No. 1154)'
Ref 8.I	Construction Industry Research and Information Association. McBain W., Wilkes D. and Retter M.. CIRIA C688, 'Flood Resilience and Resistance for Critical Infrastructure'
Ref 9.I	Highways England. CD 116, 'Geometric design of roundabouts'
Ref 10.I	Highways England. CD 109, 'Highway link design'
Ref 11.I	Highways England. CD 527, 'Sumpless gullies'
Ref 12.I	Environment Agency. 'The Environment Agency's Approach to Groundwater Protection'
Ref 13.I	Construction Industry Research and Information Association. London. Woods-Ballard,B., Wilson,S., Udale Clark,H., Illman,S., Scott,T., Ashley,R., Kellagher,R.. CIRIA C753, 'The SuDS Manual'
Ref 14.I	Highways England. HD 220, 'Vortex Separators for use with Road Drainage Systems'

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Appendix A. Drainage option advantages and disadvantages

Table A.1 lists the types of drainage discussed in this document, and details potential advantages and disadvantages of each drainage type.

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Table A.1 Advantages and disadvantages of drainage options

Drainage collector detail		Advantages	Disadvantages
Surface drainage	Combined channel and pipe drains	1) provide extra flow capacity than for a channel of the same width, reducing the number of outlets from the system and reducing, or even eliminating the need for a separate carrier pipe; 2) where space is limited (for example, in road widening schemes) they allow a narrower channel to be built than would otherwise be possible; 3) suited to in situ construction in concrete using slip forming techniques; 4) they can remove the need for a separate carrier drain in the verge and can enable flow to be carried longer distances between outlets.	1) pipes follows the gradient of the road and consequently can be quite flat allowing build-up of sediment; 2) slots (where present) can become blocked with sediment restricting inflow; 3) slots (where present) reduce the efficiency of any jetting to clear sediment.
	Combined kerb and drainage system	1) their use at roundabouts removes the need for any 'false' crowning of road-edge channels; 2) they may be economic in rock cuttings, as a cheaper option compared to carrier drain installation; 3) useful on roads with relatively flat gradients (HA 39 [Ref 7.N]); 4) useful in urban areas where there is a high incidence of utility services because they do not need as great a depth of excavation as piped system (HA 39 [Ref 7.N]).	1) prone to the build-up of sediment and debris which can impede flow into and within the system. (HA 39 [Ref 7.N]); 2) less robust than solid kerbs of equivalent dimensions (HA 39 [Ref 7.N]); 3) require linear maintenance procedures taking longer and requiring additional traffic management and lane closure than point maintenance of gully sucking; 4) at roundabouts their maintenance requires complex lane closure with traffic management.

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Table A.1 Advantages and disadvantages of drainage options (continued)

Drainage collector detail		Advantages	Disadvantages
Surface drainage	Grassed surface water channels	1) ability to treat pollution (CD 521 [Ref 9.N]); 2) peak discharge flow rate to a receiving watercourse will be less from the grassed channel. (CD 521 [Ref 9.N]).	1) prone to rutting resulting from vehicular over running; 2) require regular maintenance (grass cutting), which involves potential risk to operatives.
	Informal drainage (over the edge)	1) cost effective and easily maintained solution in rural settings.	1) can cause soil erosion, topsoil slippage, softening of the side slopes and embankment instability (HA 39 [Ref 7.N]); 2) uncontrolled growth on verges can inhibit free drainage; 3) inappropriate for usage in locations where footways or segregated cycleways abut carriageways; 4) only suitable for embankments < 1m high (HA 39 [Ref 7.N]).
	Kerbs and gullies	1) a longitudinal gradient to carry road surface runoff to outlet is not dependent upon the longitudinal gradient of the road itself and can be formed instead within a longitudinal carrier pipe; 2) different types of gully are available that provide for varying degrees of entrapment of detritus; 3) kerbs provide some structural support during pavement laying and protect footpaths and verges from vehicular overrun.	1) gullies can become blocked due to lack of maintenance; 2) side entry gullies are inefficient; 3) the permitted width of channel flow may significantly reduce the spacing between gullies when used on high speed roads.

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Table A.1 Advantages and disadvantages of drainage options (continued)

Drainage collector detail		Advantages	Disadvantages
Surface drainage	Linear drainage channels	1) may be used in both verges and central reserves on motorways (HA 39 [Ref 7.N]).	1) linear drainage channels built on relatively flat gradients are prone to the build-up of sediment and debris (HA 39 [Ref 7.N]).
	Surface water channels	1) relatively easy maintenance; 2) long lengths can be constructed quickly and fairly inexpensively; 3) it may be possible to locate channel outlets at appreciable spacings and possibly coincident with watercourses; 4) the risk to vehicles and occupants impinging on surface water channels is lower than for other types of surface drainage; 5) suited to in-situ construction in concrete using slip forming techniques (not blocks).	1) carriageways with flat longitudinal gradients may necessitate discharge of channels fairly frequently into outlets or parallel longitudinal carrier pipes in order to minimise the size of the channels; 2) presence of features such as safety fences, services, lighting columns and signs may restrict ability to use; 3) ability to install long channel lengths may be prevented by discontinuities in the verge/central reserve such as piers, abutments, slip roads, junctions, laybys, central reserve crossover points, emergency crossing points or changes in superelevation.

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Table A.1 Advantages and disadvantages of drainage options (continued)

Drainage collector detail		Advantages	Disadvantages
Surface drainage	Surface water channels with channel blocks	1) it may be possible to locate channel outlets at appreciable spacings and possibly coincident with watercourses; 2) suited to use on steep embankments (Types D, E and F) (HA 39 [Ref 7.N]); 3) suitable where positive drainage is desirable for dealing with small volumes of flow that would not justify use of the larger surface water channel. (Types A and B) (HA 39 [Ref 7.N]).	1) effectiveness of drainage channel blocks is reduced by settlement of adjacent unpaved surfaces; 2) drainage channel blocks are prone to the build-up of sediment and debris in flat areas; 3) presence of drainage channel blocks may reduce ability to undertake mechanical grass cutting; 4) should be avoided in verges subject to frequent usage by equestrians or other vulnerable users; 5) presence of features such as safety fences, services, lighting columns and signs may restrict ability to use; 6) ability to install long channel lengths may be prevented by discontinuities in the verge/central reserve such as piers, abutments, slip roads, junctions, laybys, central reserve crossover points, emergency crossing points or changes in superelevation.

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Table A.1 Advantages and disadvantages of drainage options (continued)

Drainage collector detail		Advantages	Disadvantages
Combined surface and sub-surface drainage	Combined surface and sub-surface drains (filter drains)	1) can be installed early in the construction phase and be used to manage drainage during construction (with appropriate maintenance); 2) they remove groundwater to a greater depth beneath pavement level than fin or narrow filter drains; 3) easier to construct than a solution with both surface and sub-surface drainage constructed separately; 4) easier inspection and maintenance than fin or narrow filter drains; 5) allow collection of water from drainage systems installed separately in the side-slopes of cuttings; 6) enable rapid removal of runoff from the road and verge surface (HA 39 [Ref 7.N]); 7) can manage a wide range of flows (HA 39 [Ref 7.N]); 8) particularly suited to dealing with sub-surface water flows, which can vary as the water table fluctuates (HA 39 [Ref 7.N]); 9) generally have an exceptionally large groundwater capacity which can extend as a cut-off below the capping layer (HA 39 [Ref 7.N]); 10) removes sediment and attached pollutants providing a degree of water quality treatment.	1) surface failure of embankments and pavement failures; 2) risk of stone scatter where subject to vehicular over run.

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Table A.1 Advantages and disadvantages of drainage options (continued)

Drainage collector detail		Advantages	Disadvantages
Sub-surface drainage	Fin drain	1) can be installed at the edge of the unbound pavement construction allowing a range of edge collection systems to be constructed above.	1) can be unsuitable for dealing with high groundwater flows or where a longitudinal carrier drain is necessary to transport surface-water runoff from the carriageways (HA 39 [Ref 7.N]); 2) ground stability issues are possible during excavation of and working within the narrow trenches needed for Types 5, 6 and 7 (Volume 3 of MCHW [Ref 11.N]).
	Narrow filter drain	1) can be installed at the edge of the unbound pavement construction allowing a range of edge collection systems to be constructed above.	1) can be unsuitable for dealing with high groundwater flows or where a longitudinal carrier drain is necessary to transport surface-water runoff from the carriageways (HA 39 [Ref 7.N]).

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Appendix B. Pollution control components

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Table B.1 Pros and cons of pollution control components

Drainage component	Advantages	Disadvantages	Design notes
Combined kerb and drainage blocks	1) they can attenuate flow due to the high storage capacity of their designl 2) their use can reduce the size of attenuation storage or retention ponds where utilised in combination with each other.	1) sediment drop out can occur at inlets resulting in road-edge debris requiring additional road sweeping maintenance; 2) Standard jetting operations result in large loss of water from the kerb units. This may increase time on site and vehicle movements as well as resulting in debris spreading across the carriageway and thus additional road sweeping maintenance.	1) check catchment sediment load and gradients of drainage to confirm they have suitable load carrying capacity.
Combined surface and sub-surface drains	1) they can provide spillage containment if adequate downstream control such as penstock or handstop is provided; 2) the filter media can adsorb suspended solid pollutants and heavy hydrocarbons, reducing downstream pollution risk from routine runoff; 3) inclusion of an over-sized carrier drain can provide flow control.	1) where routine runoff causes a build-up of pollutant in the filter media, maintenance requirements may be increased (see HD 217 [Ref 1.N]); 2) maintenance or replacement of filter media may be needed if contaminated by a serious accidental spillage; 3) risk of stone scatter where subject to vehicular over run.	

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Table B.1 Pros and cons of pollution control components (continued)

Drainage component	Advantages	Disadvantages	Design notes
Ditches	1) unlined ditches can allow infiltration of runoff through soil and vegetation, particularly where residence times are long; 2) lined ditches can act as containment basins if located between the road drain and receiving watercourses.	1) scientifically robust information on their treatment performance is limited; 2) ditches with concrete or similar facing do not have the same treatment potential as unlined ditches, but can be adapted to contain spillages; 3) where unlined ditches are located above permeable strata, there is a risk that highway runoff will infiltrate and potentially contaminate any underlying aquifer; 4) unlined ditches encourage vegetation growth that can hamper access and operational ability as well as increased maintenance requirement.	1) the direct input of a pollutant to groundwater without percolation through soil or subsoil is an offence under Section 12(1) of the Environmental Permitting Regulations [Ref 7.I]; 2) ditches with shallow side slopes have similar properties to swales; 3) where lined ditches are used as containment basins they should have a minimum of 25 m^3 capacity and have a downstream control that can be shut or blocked in the event of accidental spillage of pollutants on the road.
Informal drainage (over the edge)	1) they can provide, in some circumstances, a degree of pollution control as highway runoff is allowed to filter through vegetation on the slope; 2) pollution control is possible with informal drainage, using a downstream control.	1) where informal drainage is used above permeable strata, there is a risk that highway runoff will infiltrate and potentially contaminate any underlying aquifer.	1) toe ditches associated with informal drainage can be lined to prevent percolation through the soil or subsoil.

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Table B.1 Pros and cons of pollution control components (continued)

Drainage component	Advantages	Disadvantages	Design notes
Kerbs and gullies	1) ability to capture potentially contaminated sediments during normal rainfall events prior to discharge into a receiving watercourse; 2) provide initial stage of interception of spillages.	1) less effective at trapping finer grained sediment than coarser grained sediment; 2) high inflow rates can cause re-suspension of sediments and mixing of oils with the water in the gully pot; 3) contaminated water can discharge from the gully pot into the receiving drainage network or watercourse.	1) re-suspension or mixing of oils can be avoided by ensuring that the gradient of the pipe leading to the gully is as shallow as possible whilst still providing adequate hydraulic performance; 2) sumpless gullies should be considered where this is not possible.
Penstocks and handstops	1) they can provide spillage containment if they are closed in time.	1) failure to open penstock after spillage incident (or closure of penstock due to vandalism or equipment failure etc) could result in flooding or scouring following breach of the headwall or ditch; 2) regular maintenance needed; 3) handstops not appropriate for larger systems.	1) the size of handstops should be such that the plate can be lifted manually.
Piped systems	1) they can provide spillage containment if adequate downstream control such as penstock or handstop is provided.		

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Table B.1 Pros and cons of pollution control components (continued)

<table>
<tr><th>Drainage component</th><th>Advantages</th><th>Disadvantages</th><th>Design notes</th></tr>
<tr><td>Reservoir pavements</td><td>1) they can allow full infiltration of surface water into the subgrade or partial infiltration combined with capture for controlled release elsewhere;
2) can provide economical drainage solution.</td><td>1) only permitted in locations outside the main trafficked lanes (see HD 221 [Ref 1.I]).</td><td>1) use in main trafficked lanes requires departure from standard.</td></tr>
<tr><td>Sedimentation tanks</td><td></td><td>1) they are not reliable for the removal of dissolved copper and zinc.</td><td>1) efficiency of sediment removal depends on factors such as inflow velocity, separator size, retention time, maintenance frequency and settlement time of individual particles;
2) they should not be relied upon to remove dissolved copper and zinc.</td></tr>
<tr><td>Surface water channels</td><td></td><td rowspan="2">1) where channels are not self-cleansing, deposition of gross pollutants and sediments is likely to occur;
2) ponding of water behind such deposited material can cause safety threat to road users.</td><td rowspan="2">1) to avoid sediment build up, designs should ensure that surface water channels are self-cleansing and sediments deposited in a downstream system;
2) channels designed so that emergency response kits can be used in them can act as a pollution control measure for spillages.</td></tr>
<tr><td>Surface water channels with channel blocks</td><td></td></tr>
</table>

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Table B.1 Pros and cons of pollution control components (continued)

Drainage component	Advantages	Disadvantages	Design notes
Weirs and baffles	1) they can act as both pollution and flood control devices; 2) baffles can be placed in both open channels and ditches.		1) where weirs are used for spillage control, they should be designed with a notch or orifice that can readily be blocked by a sandbag in an emergency; 2) where baffles are used for spillage control, they should be designed so that they can readily be blocked in an emergency; 3) where baffles are used for spillage control, the design should include at least 25 m^3 of containment.

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