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Transport Infrastructure Ireland

## TII Publications



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# Determination of Pipe and Bedding Combinations for Drainage Works

**DN-DNG-03070**  
March 2015

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## Document Attributes

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## NRA DMRB and MCDRW References

For all documents that existed within the NRA DMRB or the NRA MCDRW prior to the launch of TII Publications, the NRA document reference used previously is listed above under 'historical reference'. The TII Publication Number also shown above now supersedes this historical reference. All historical references within this document are deemed to be replaced by the TII Publication Number. For the equivalent TII Publication Number for all other historical references contained within this document, please refer to the TII Publications website.

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**Determination of Pipe and Bedding  
Combinations for Drainage Works**

**March 2015**

**Summary:**

This Standard describes the method of selecting suitable combinations of drainage pipes and bedding types to meet given loading requirements.

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**VOLUME 4      GEOTECHNICS AND  
DRAINAGE**

**SECTION 2      DRAINAGE**

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**PART 5**

**NRA HD 140/15**

**DETERMINATION OF PIPE AND BEDDING  
COMBINATIONS FOR DRAINAGE WORKS**

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# 1. INTRODUCTION

## General

- 1.1 The NRA Specification for Road Works (NRA SRW) permits a range of pipes of different material properties to be used for drainage works in roads. The NRA Road Construction Details (NRA RCD) also allow a choice in the method of bedding pipes where the degree of structural support given to the pipe when it is laid in trench varies. In general, not all possible combinations of pipe and bedding selected from the permitted options for each will necessarily be suitable for a particular design and permitted combinations have therefore to be specified for each contract.
- 1.2 The 2015 revision of the NRA's drainage standards was precipitated by post-doctoral research carried out under the NRA's Research Fellowship Programme and mentored by the NRA's Environment Unit. This research looked at the impacts of national road drainage systems on both surface and ground water. The research concluded that the NRA's drainage standards needed to be expanded to promote the use of sustainable drainage systems and to maximise environmental benefits. A report entitled *Drainage Design for National Road Schemes – Sustainable Drainage Options* (NRA, 2014) documents this research and provides useful background reading to the NRA's drainage standards. This document is available at: [nrastandards.nra.ie/latest/other-nra-documents](http://nrastandards.nra.ie/latest/other-nra-documents)

## Scope

- 1.3 The charts presented in this Standard shall be used to select the combinations of type of pipe and bedding from the permitted alternatives in the NRA Specification for Road Works and Road Construction Details to meet given loading requirements. They are a revision of the charts previously published in UK Highways Agency HA 40 and take into account updates of British Standards and Euronorms for some pipes and loading patterns in accordance with BS 5400: Part 2 as implemented by NRA BD 37 Loads for Road Bridges. Charts for an additional category of loading for pipes laid in filter drains have been included.
- 1.4 The range of pipes included in the charts is listed in Appendix A. The charts may be applicable for the design of pipe types not covered in this Standard but the designer should satisfy themselves that the relevant physical properties are comparable to those listed. Chapter 2 of this Standard outlines the design basis for deriving the charts.
- 1.5 The types of pipe bedding that are covered are those shown in RCD/500/20 and RCD/500/21.
- 1.6 The charts are intended for the widest range of pipe bedding combinations and are based on the worst case scenario from a range of manufactured pipe thicknesses, possible trench widths and bedding factors and are therefore conservative. Designers should, when justified, consider the merits of individual designs to suit local conditions. For example when the trench width can be closely controlled and the pipe outside diameter is accurately known, a specific design check may allow a pipe to be safely used outside the tabulated depth range or alternatively permit a lower strength pipe and/or bedding to be used at the given depth.
- 1.7 This Standard does not cover hydraulic design requirements for pipes; refer to NRA HD 33 Drainage Systems for National Roads.
- 1.8 The principles outlined in this Standard apply to all National Roads projects.

### **Implementation**

- 1.9 This Standard shall be used forthwith for all schemes for the construction and/or improvements of national roads. It shall be applied to the design of schemes already being prepared unless, in the opinion of the National Roads Authority, application would result in significant additional expense or delay progress. In such cases, Design Organisations shall confirm the application of this Standard to particular schemes with the National Roads Authority.

## 2. DESIGN CONSIDERATIONS

### Range of Bedding Types

- 2.1 Methods of bedding pipes are shown in RCD/500/20 for filter drains and RCD/500/21 for carrier drains. These different beddings provide varying degrees of support to the pipe. In the case of combined surface and sub-surface drains the granular bedding and surround additionally functions as a filter medium. Not all possibilities that would give satisfactory bedding are included in Series 500 of NRA RCD; the choice has been restricted to save granular material and to combinations most likely to be of use. Bed types A, B, F, N and S in RCD/500/21 are for use with rigid pipes and bed types S and T with flexible pipes. Type T bedding for rigid pipes is less likely to be economic for the same degree of support. Type Z is for use with any type of pipe for permanent protection against mechanical damage, for example when subsequent excavations are required alongside the pipeline, for pipe junctions and where remedial measures are required. It converts a relatively flexible pipeline into a rigid beam of low flexural strength, susceptible to damage by differential settlement and is uneconomic to use except where essential. Flexibly jointed pipes shall have a compressible filler to break the Type Z surround at every joint or second joint for short pipes. All bed types shown in RCD/500/20 are suitable for both rigid and flexible pipes.

The specification requirements for bedding, backfill material and construction are given in the Series 500 of NRA SRW.

### Loading on Pipes

- 2.2 The design charts cater for three categories of loading conditions, which include imposed surface loads together with soil and water loads as appropriate. The latter have been considered only for pipes greater than 600mm diameter.
- a) Main road loading is applicable to pipes under pavements including cross drains and for pipes in verges where heavy loads may occur. It consists of 8 wheel loads each of 112.5 kN including impact factor, in the HB loading pattern corresponding to 45 units of HB loading to BS 5400: Part 2 as implemented by NRA BD 37.
  - b) Field loading is applicable to fields, gardens and lightly trafficked access tracks. It consists of two wheels 1.0m apart, each of a static load of 30 kN with an impact factor of 2.0, giving a total load for each wheel of 60 kN.
  - c) Filter drain loading is applicable to pipes in filter drains in verges and central reserves. It corresponds to the outer verge loading specified in BS 5400: Part 2 as implemented by NRA BD 37 with 30 units of HB loading, each wheel load being 62.5 kN. Only two wheel loads are considered but with an increased impact factor of 1.4 giving a total load for each wheel of 87.5 kN. Filter drains not immediately adjacent to the carriageway may, if appropriate, be designed for field loads.

### Loads during Construction

- 2.3 Pipes laid under and adjacent to roads are likely to be subject to higher loads during construction than in service. The charts given in this Standard are not applicable to this situation and a specific design check shall be required and documented. The following safeguards may be considered when pipelines have to be crossed by construction traffic and plant:



- a) Temporary bridging or slabbing or increasing the cover over shallow pipes with suitable material to be at least 1m for general construction traffic or 2m where a haul road is constructed or motorised scrapers are used.
- b) Provision of a stronger design for the pipe and bed combination. Wheel loads of 180 kN in the HB pattern can be used to achieve a strength suitable for general construction traffic. Wheel loads of 280 kN are necessary for haul roads and motorised scrapers. More detailed advice is given in Reference 5.4.

### Settlement

- 2.4 Pipes in highly compressible soils shall, where feasible, be avoided. Where this is not possible, only granular beds (types B, F and S) shall be permitted and the use of a geotextile filter on the floor of the trench should be considered to prevent contamination of the bedding material.

### Rigid Pipe Design

- 2.5 Rigid pipes are those which fracture before significant deformation occurs (eg clayware, concrete). The derivation of the design charts for rigid pipes in this Standard is in accordance with the principles given by Young, O'Reilly and Brennan. Reference should be made to these documents for the full theory and for the design of special cases (see Clauses 1.5 and 2.3).

The safe supporting strength of the pipe/bed combination  $W_s$  is given by:

$$W_s = \frac{W_t F_m}{F_s}$$

- Where
- |       |   |   |
|-------|---|---|
| $W_t$ | = | Crushing strength as indicated in the relevant British Standard |
| $F_m$ | = | The bedding factor  |
| $F_s$ | = | Factor of safety taken as 1.25                                  |

The allowable depth range is determined such that  $W_s > W$  where  $W$  is the total load on a particular pipe at a given depth.

The load on the pipe as found from the "narrow trench" equation (Ref 5.4) is directly related to the trench width. Thus if the width of trench constructed exceeds the assumed design width then the load on the pipe may be greater than the design load. This equation has been used for pipes greater than 375mm but with the trench width conservatively taken at least 700mm greater than the pipe outside diameter. For all pipes below 375mm the "wide trench" equation (Ref 5.4) is used and in this case no restriction on the trench width is necessary.

### Bedding Factor

- 2.6 The bedding factor is the ratio of the failure load for the pipe installed in the ground to its failure load in a crushing test machine and is generally greater than unity. The bedding factors for rigid pipe design are obtained from I.S. EN 1295-1 and are reproduced below. These are the values of the bedding factors that have been assumed for the bed types shown in Series 500 of NRA RCD.
- a) Carrier Drains (RCD/500/21)  
Refer to Table NA7, I.S. EN 1295-1: Narrow Trench Conditions

Bed Type	Description	Bedding Factor
A	Concrete Bed	2.6
B	Granular Bed & Haunch	1.9
F	Granular Bed	1.5
N	Granular or Sandy Bed	1.1
S	Granular Surround	2.2

Though not constituting a bedding type in accordance with I.S. EN 1295-1 the following condition may be assumed:

Z	Concrete Surround	2.6
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b) Filter Drains (RCD/500/20)

For filter drains, bed types I and K have the lowest value (1.9) of the types shown: this value has been used in order to allow for the full range of likely filter materials. The bedding factors appropriate to the other types are 2.2 for type H and 2.6 for type G.

### Flexible Pipe Design

2.7 Flexible pipes are those which deform to a significant extent before collapse (eg plastics, steel). Commonly, flexible pipes used for road drainage are manufactured from thermoplastic materials and are specified in accordance with Series 500 of NRA SRW.

The design charts in Appendix B are based on a design method specified in I.S. EN 1295 for flexible pipes which takes into account the relative stiffness of the pipe and the surrounding soil.

The criteria for obtaining the safe depth ranges are a maximum ring deflection (ie change in diameter) of 5% and a factor of safety against ring buckling of 2.

2.8 The degree of compaction of the pipe bedding material has a significant effect on the results and consequently, the worst case scenario, with the material in a loose condition, has been assumed. The corresponding E values used are:

Bed Type	Description	Surround E Value
S (RCD/500/21)	Granular Surround	5MPa
T (RCD/500/21)	Sandy Surround	2MPa
All (RCD/500/20)	Filter Drains	5MPa

The strength of a thermoplastic pipe is a function of the initial pipe stiffness and the E modulus of the native soil material, through which the trench has been excavated and that of the pipe bedding and surround. The compaction of the sidefill material is, therefore, fundamental to the performance of flexible/semi-rigid pipes.

## Design Assumptions

- 2.9 The preference for granular bedding material is based on this being more or less self-compacting and producing adequate support with little attention to the compaction. Research has shown that materials that constitute Class T bedding can provide a greater degree of support to flexible pipes. However, this is dependent on the compaction applied to the sidefill materials and hence requires a certain degree of care to be taken during the placement and compaction of the material. The compaction that may occur as subsequent backfill layers are placed is not sufficient as deformation of the pipe will occur during the backfill operation until the sidefill material is subsequently compacted to resist the deformation of the pipe. Hence, it is recommended that Class T bedding is not specified for main road loading situations until such time as an adequate method of monitoring the level of compaction is developed.

The arching factor used (Ref 5.7) is unity.

Semi-rigid and flexible pipe embedments are set out in Table NA8 of I.S. EN 1295-1.

Thermoplastic pipes principally comprise those manufactured from PVC-u, polyethylene and polypropylene, though there are variations on these and other polymers less frequently used. The performance of each polymer is different and is dependent on the initial pipe stiffness (STIS), and the creep ratio (Refs 5.10 and 5.9, respectively).

## Withdrawal of Trench Supports during Backfilling

- 2.10 When pipes are laid in trenches where the sides are supported by trench sheeting, the values of the soil modulus and the bedding angle of friction are reduced by a coefficient depending on the stage during the backfill process at which the sheeting is withdrawn. If the sheeting is withdrawn in stages before each layer of backfill is compacted then the coefficient shall be taken as unity. If the sheeting, or box, is removed in steps after the backfill is compacted then the coefficient shall be taken as 0.6. This value is recommended by most pipe manufacturers. Where the supports are withdrawn after the trench is completely backfilled the coefficient shall be taken as 0.2. It is strongly advised that the latter procedure should not be used.

### 3. WORKED EXAMPLE

3.1 The design charts for determining safe pipe/bedding combinations are given in Appendix B. Figures A, B and C of Appendix B are used to determine a pipe group number for three categories of loading corresponding to main road, field and filter drain loadings respectively. Having determined the group number, Figures D or C are then used to obtain the safe combination for carrier drains or filter drains, respectively.

As an example, consider a carrier pipe 300mm in diameter located in the carriageway verge with depth of cover of 2.0m minimum and 3.0m maximum.

For the location of the pipe it is decided that main road loading should be assumed (Chapter 2) and therefore Figure A would be applicable.

From Figure A the group number corresponding to the minimum and maximum depth of cover to the pipe is found to be Group 7.

From Figure D the permitted combinations are indicated by those having group numbers greater than or equal to 7. For a 300mm diameter pipe these are found to be:

Pipe	Class	Bedding Type
Vitrified Clay	160	ASBF
	200	ASBFN
Precast Concrete	120	ASB
Thermoplastic		ST

For filter drains the procedure is similar except that the bedding strength provided by all filter drain types shown in Series 500 of NRA RCD is acceptable (see Chapter 2). Thus the design is a check on the suitability of the pipe for the given loading.

Using the previous example of a 300mm diameter pipe from Figure C, the group number is found to be 4. From Figure E suitable pipes for a group number equal to or greater than 4 are found to be:

Pipe	Class
Vitrified Clay	160
	200
Precast Concrete	120
Thermoplastic	Various

It should be noted that in Figures D and E some group numbers are omitted because either the particular class of pipe is not usually manufactured in that diameter or the strength of the given pipe bed combination is insufficient.

3.2 Alternatively, the designer or scheduler may refer to the 'Materials Selection Manual for Sewers, Pumping Mains and Manholes' where a number of worked examples are given for pipes in a range of materials. When the properties of the pipe materials are known, the methods detailed in the Manual may be used to verify the suitability of the pipes in accordance with the schedule in Appendix 5/1 (see Chapter 4).

## 4. SPECIFICATION REQUIREMENTS

- 4.1 The NRA Specification for Road Works requires contract-specific information to be provided by the designers. The permitted pipe/bed combinations for carrier drains and the permitted pipe types and drain types for filter drains shall be set out in a schedule which will form part of Appendix 5/1 in Series 500 of the Specification. An example of a format for this schedule is given in Appendix C.

## 5. REFERENCES

- 5.1 **NRA Manual of Contract Documents for Road Works (NRA MCDRW)**
- a) NRA Specification for Road Works (NRA SRW) (MCDRW 1)
  - b) Notes for Guidance on the Specification for Road Works (NRA NGSRW) (MCDRW 2)
  - c) Road Construction Details (NRA RCD) (MCDRW 4)
- 5.2 **NRA Design Manual for Roads and Bridges (NRA DMRB)**
- a) NRA BD 37 Loads for Road Bridges
  - b) NRA HD 33 Drainage Systems for National Roads
- 5.3 Materials Selection Manual for Sewers, Pumping Mains and Manholes. Water Services Association, London 1993.
- 5.4 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.
- 5.5 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.
- 5.6 The Development of a New Design Method for Buried Flexible Pipes. J E Gumbel, M P O'Reilly, L M Lake and D R Carder. Proceedings Europipe 82, Basle (Access Conferences London 1982).
- 5.7 A New General Design Method for Buried Flexible Pipes. Mott, Hay and Anderson. (Unpublished TRRL Ref No CON/6102/21).
- 5.8 UNE ENV 1046: 2002. Plastics piping and ducting systems - Systems Outside Building Structures for the Conveyance of Water or Sewage - Practices for Installation Above and Below Ground.
- 5.9 I.S. EN ISO 9967: 2007 Thermoplastics pipes - Determination of Creep Ratio. National Standards Authority of Ireland.
- 5.10 I.S. EN ISO 9969: 2007. Thermoplastic pipes - Determination of Ring Stiffness. National Standards Authority of Ireland.
- 5.11 I.S. EN 1295-1: 1998. Structural Design of Buried Pipelines Under Various Conditions of Loading - Part 1: General Requirements. British Standards Institution.
- 5.12 I.S. EN 1610: 1998. Construction and Testing of Drains and Sewers. National Standards Authority of Ireland.
- 5.13 I.S. EN 598: 2007+A1: 2009. Ductile Iron Pipes, Fittings, Accessories and their Joints for Sewerage Applications - Requirements and Test Methods. National Standards Authority of Ireland.
- 5.14 Drainage Design for National Road Schemes – Sustainable Drainage Options. National Roads Authority. 2014.

## 6. ENQUIRIES

- 6.1 All technical enquiries or comments on this document, or any of the documents listed as forming part of the NRA DMRB, should be sent by e-mail to [infoDMRB@nra.ie](mailto:infoDMRB@nra.ie), addressed to the following:

Head of Network Management, Engineering Standards & Research  
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St Martin's House  
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Dublin 4



.....  
Pat Maher  
Head of Network Management,  
Engineering Standards & Research

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## APPENDIX A: TYPES OF PIPE TO WHICH CHARTS ARE APPLICABLE

A.1. The charts in Appendix B are applicable to the following types of pipe:

- a) Vitrified clay pipes to:
  - i) I.S. EN 295: 2013 to classes L 95, 120, 160 and 200
  - ii) BS 65: 1991
- b) Precast concrete pipes classes to the following standards:
  - i) BS 5911: 1: 2002+A2: 2010
  - ii) BS 5911: 5: 2004+A1: 2010 (Pre-stressed non pressure pipes and fittings)
  - iii) I.S. EN 1916: 2002 Concrete pipes and fittings, unreinforced, steel fibre and reinforced)
- c) Thermoplastic pipes to the following standards:
  - i) BS 4660: 2000 (size 110mm & 160mm diameter)
  - ii) I.S. EN ISO 1452-1: 2009 Plastic piping systems for water supply and for buried and above ground drainage and sewerage under pressure
  - iii) I.S. EN 1401-1: 2009 Plastic piping systems for non-pressure underground drainage and sewerage (PVC-U)
  - iv) I.S. EN 1852-1: 2009 Plastic piping systems for non-pressure underground drainage and sewerage (PP)
  - v) I.S. EN 12666-1: 2006 Plastic piping systems for non-pressure underground drainage and sewerage (PE)
- d) Ductile iron pipes to I.S. EN 598: 2007+A1: 2009
- e) Cast iron pipes to BS 437: 2008
- f) Glass reinforced plastic pipes (GRP) to:
  - i) I.S. EN 14364: 2013 Plastic piping systems for drainage and sewerage with or without pressure (GRP)



## APPENDIX B: CHARTS OF BEDDING/PIPE COMBINATIONS

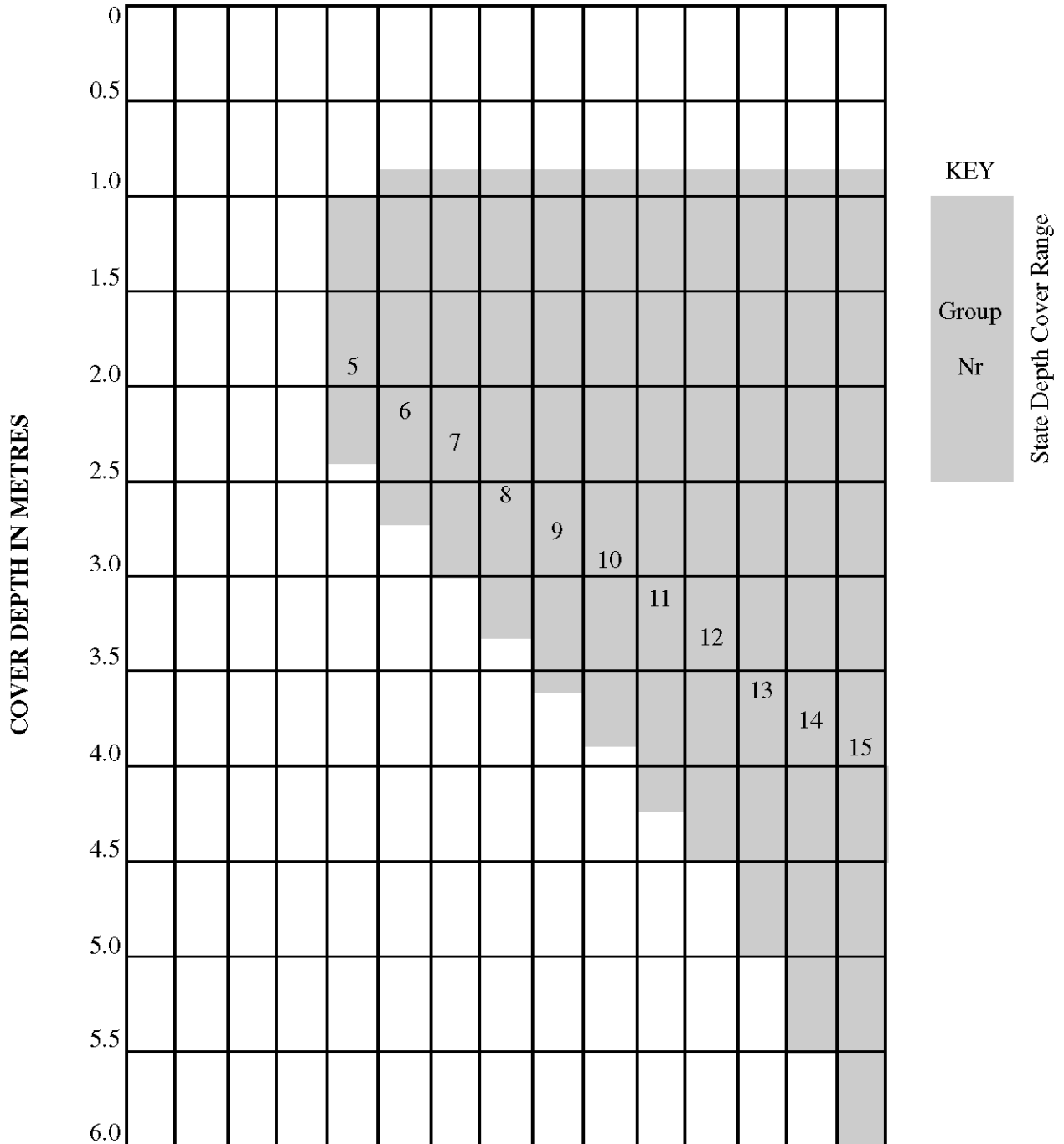


Fig. A - Carrier Drains - Main Road Loading

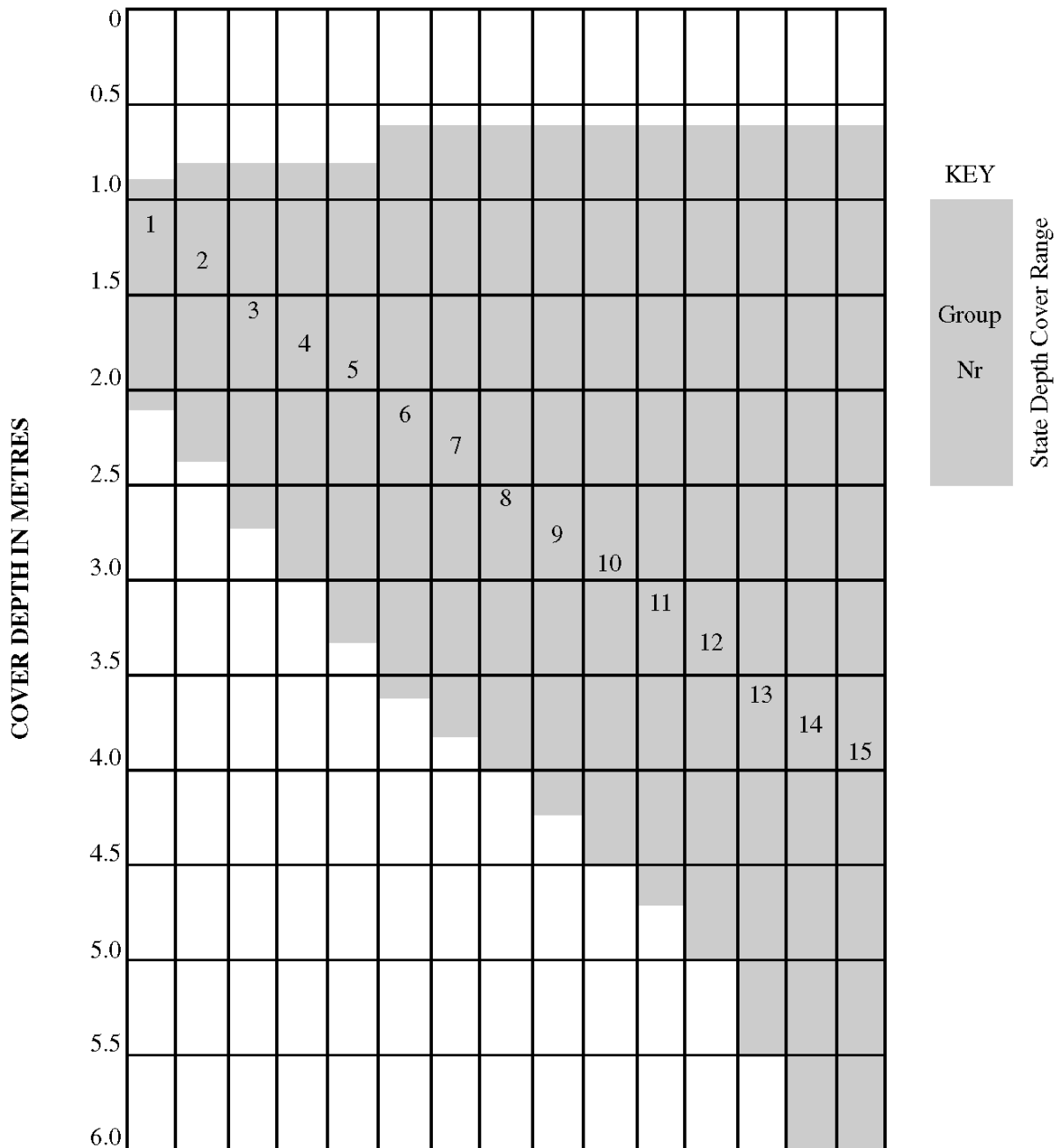


Fig. B - Carrier Drains - Field Loading

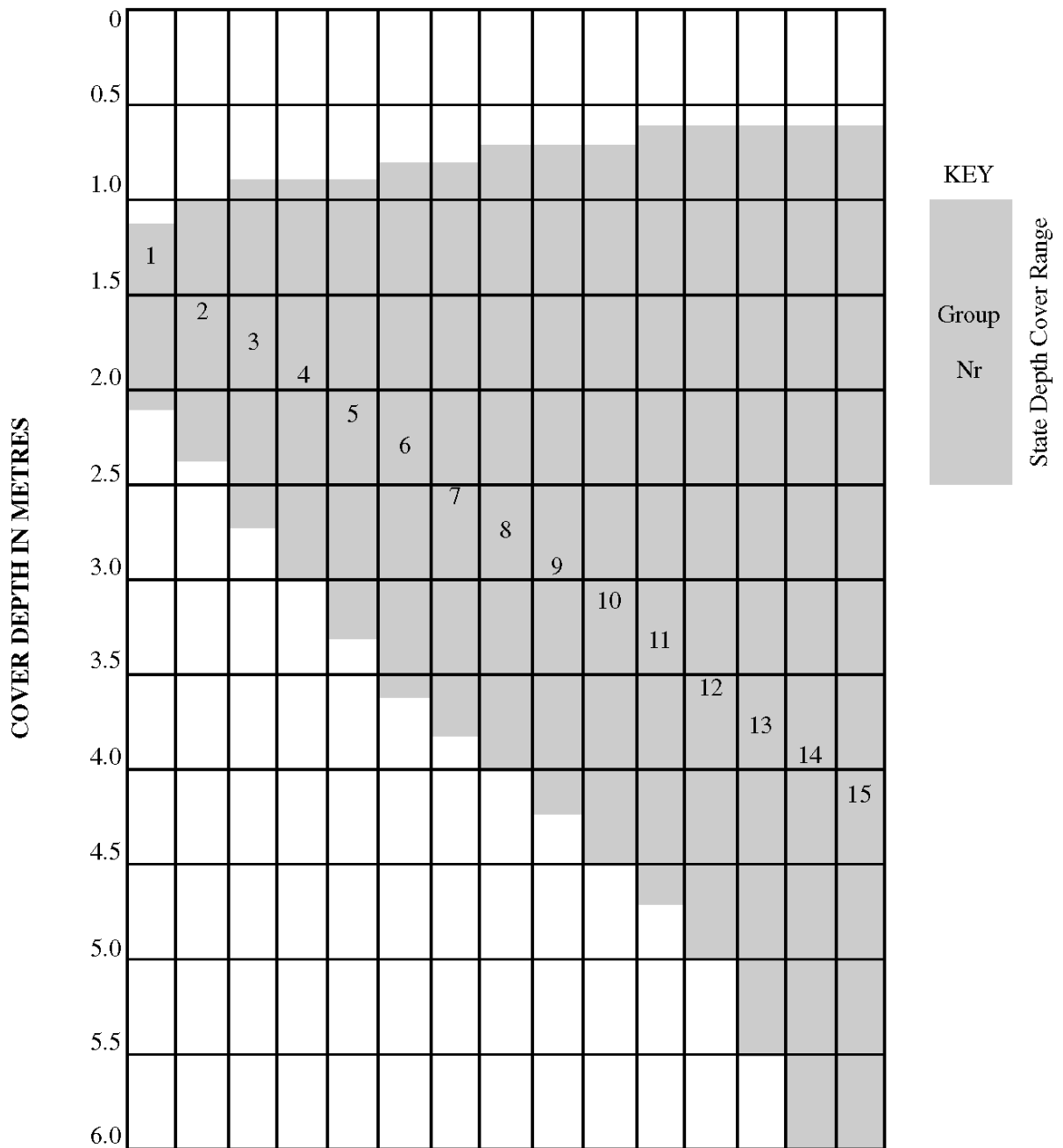


Fig. C - Filter Drains

## APPENDIX C: GROUP NUMBERS FOR DETERMINING ALLOWABLE PIPES

Pipe Material	Rigid																							
	Pipe Class	Vitrified Clay												Concrete										
		160				200				120														
Bed Type	A	S	B	F	N	A	S	B	F	N	A	S	B	F	N									
100	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15									
150	15	15	15	15	12	15	15	15	15	14														
200	15	15	15	14	5	15	15	15	15	14														
225	15	15	15	14	5	15	15	15	15	10														
250	15	15	15	14	5	15	15	15	15	10														
300	15	15	15	15	6	15	15	15	15	10	15	15	12	6	1									
375	15	15	15	15	7	15	15	15	15	11	15	14	15	6	1									
400	15	15	15	15	6	15	15	15	15	11														
450	15	15	15	15	7						15	14	10	4										
500	15	15	15	15	7																			
525											15	14	10	4										
600											15	15	12	5	1									
675											15	15	12	5	1									
700																								
750											15	15	12	5	1									
800																								
825											15	14	11	5	1									
900											15	14	12	7	2									

Fig. D1: Carrier Drains – Group Numbers for Determining Allowable Pipe/Bed Combinations

		Non-Rigid														
		Semi-Rigid						Flexible/Thermoplastic								
Pipe Material		GRP			Ductile Iron			Stiffness > 6KPa			Others by design					
Pipe Class		5 kN/m <sup>2</sup>		10 kN/m <sup>2</sup>		K9			PVCu			PP/PE				
Bed Type		S	T	S	T	S	T	S	T	S	T	S	T	max soil E < 5	8 pe	
Nominal Pipe Diameter (mm)	100	15		15		15		14		14		12		13		
	150	15		15		15		14		14		12		13		
	200	15		15		15		14		14		12		13		
	250	15		15		15		14		14		12		13		
	300	15		15		15		14		14		12		13		
	350	15		15		15		14		14		12		13		
	400	15		15		15		14		14		12		13		
	500	15		15		15		14		14		12		13		
	600	15		15		15		14		14		12		13		
	700	15		15		15		14		14		12		13		
	800	15		15		15		14		14		12		13		
	900	15		15		15		14		14		12		13		

SDR 41 pipes are specified by external diameter  
The nominal diameters shown are the nearest  
equivalent internal diameter

Fig. D.2: Carrier Drains - Group Numbers for Determining Allowable Pipe/Bedding Combinations

	Pipe Material	Vitrified Clay		Concrete		Thermoplastic		
	Pipe Class	160	200	120		Structured Wall	SDR 41	
Nominal Pipe Diameter (mm)	100	15	15			15		100
	150	15	15			15	15	110
	225	15	15			15		150
	250	15	15			15	15	160
	300	15	15	15		15	15	200
	350					15		225
	375	15	15	15			15	250
	400	15	15			15		260
	450	15	15	15		15		300
	500	11	15			15		360
	525			15		15		400
	600	11		15		15		450
	675			15		15		500
	700					15		600
	750			15		15		700
	800					15		750
	825			15		15		900
900			15					

**Fig. E: Filter Drains – Group Numbers for Determining Allowable Pipes**

Pipe Diameter (mm)	Pipe Group No	Vitrified Clay		Concrete	Ductile Iron	GRP	Thermoplastic	
		160	200				Structured Wall	SDR 41
150	2	ASBFN	ASBFN	120	ST		ST	
160	5							ST
150	5	ASBFN	ASBFN		ST		ST	
200	7				ST		ST	ST
225	2	ASBFN	ASBFN				ST	
225	7	ASBF	ASBFN				ST	
300	4	ASBFN	ASBFN	ASB	ST	ST	ST	
400	8	ASBFN	ASBFN		ST	ST	ST	
600	7			ASB	ST	ST	ST	
750	11			ASB			ST	

**Carrier Drains**

Example of Schedule for Inclusion in Appendix 5/1 of the Specification

Drain Type (Lower Trench) Refer to RCD/500/1 or Contract Drg nr:	Pipe Diameter (mm)	Pipe Group Number	Vitrified Clay		Precast Concrete	Thermoplastic	
			160	200		Structured Wall	SDR 41
G,H,I	150	4			120		
K	250	2					

**Filter Drains**

= permitted type

**Example of Schedule for inclusion in Appendix 5/1 of the Specification**







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