VOLUME 4 GEOTECHNICS AND DRAINAGE
SECTION 2 DRAINAGE

PART 5

HA 40/01

DETERMINATION OF PIPE AND BEDDING COMBINATIONS FOR DRAINAGE WORKS

SUMMARY

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

INSTRUCTIONS FOR USE

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

1. This document supersedes HA 40/89, which is now withdrawn.

2. Remove existing contents page for Volume 4 and insert new contents page for Volume 4 dated November 2001.

3. Remove HA 40/89, which is superseded by HA 40/01, and archive as appropriate.

4. Insert HA 40/01, in Volume 4, Section 2, Part 5.

5. Archive this sheet as appropriate.

Note: A quarterly index with a full set of Volume Contents Pages is available separately from The Stationery Office Ltd.

THE HIGHWAYS AGENCY

SCOTTISH EXECUTIVE DEVELOPMENT DEPARTMENT

THE NATIONAL ASSEMBLY FOR WALES
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THE DEPARTMENT FOR REGIONAL DEVELOPMENT
NORTHERN IRELAND

Determination of Pipe and Bedding Combinations for Drainage Works

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REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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Contents

1. INTRODUCTION

General

1.1 The Specification for Highway Works (MCHW1 - SHW) (Ref 1) permits a range of pipes of different material properties to be used for drainage works in highways. The Highway Construction Details (MCHW3 - HCD) (Ref 1) also allows 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.

Scope

1.2 The charts presented in this Advice Note should be used to select the combinations of type of pipe and bedding from the permitted alternatives in the SHW and HCD to meet given loading requirements. They are a revision of the charts previously published in 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 BD 37 (DMRB1.3) (Ref 3). Charts for an additional category of loading for pipes laid in filter drains have been included.

1.3 The range of pipes included in the charts are listed at Appendix A. The charts may be applicable for the design of pipe types not covered in this Advice Note but the designer should be satisfied that their relevant physical properties are comparable to those listed. Section 2 of this Advice Note outlines the design basis for deriving the charts.

1.4 The types of pipe bedding that are covered are those shown in the Highway Construction Details drawings Fl and F2 and are reproduced at Appendix B.

1.5 The charts are intended for the widest range of pipe bedding combinations and are based on the worst case 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.

1.6 This Advice Note does not cover hydraulic design requirements for pipes.

Implementation

1.7 This Advice Note should be used forthwith for all schemes currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

2. DESIGN CONSIDERATIONS

Range of Bedding Types

2.1 Methods of bedding pipes are shown in the Highway Construction Details, drawing Fl for carrier drains and F2 for filter drains (see Appendix B). These different beddings provide varying degrees of support to the pipe. In the case of filter drains the granular bedding and surround additionally functions as a filter medium. Not all possibilities that would give a satisfactory bedding are included in the HCD, 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 drawing Fl are for use with rigid pipes (Section 2.5) and bed types S and T with flexible pipes (Section 2.7). 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 should have a compressible filler to break the Type Z surround at every joint or second joint for short pipes. All bed types shown in drawing F2 are suitable for both rigid and flexible pipes.

The specification requirements for bedding, backfill material and construction are given in the 500 series of clauses of the Specification for Highway Works (Ref 1).

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 has 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 BD 37 (DMRB1.3) (Ref 3).

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 BD 37 (DMRB1.3) (Ref 3) 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 Advice Note are not applicable to this situation and a specific design check will usually be required. 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 4.

Settlement

2.4 Pipes in highly compressible soils should where feasible be avoided. Where this is not possible, only granular beds (types B, F and S) should 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 Advice Note is in accordance with the principles given by Young, O'Reilly and Brennan (Refs. 4 and 5). Reference should be made to these documents for the full theory and for the design of special cases (see Sections 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 (see Section 2.6)

F_s = Factor of safety taken as 1.25

The allowable depth range is determined such that Ws > 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 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 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 BS EN 1295-1 (Ref 11) and are reproduced below. These are the values of the bedding factors that have been assumed for the bed types shown in HCD.

a. Carrier Drains (Drawing Fl)

Refer to Table NA7, BS 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 BS EN 1295-1 the following condition may be assumed

Z	Concrete Surround	2.6

b. Filter Drains (Drawing F2)

For filter drains, bed types I, K and M 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 types G, J and L.

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 highway drainage are manufactured from thermoplastic materials and are specified in accordance with Clause 518 of SHW (MCHW1) (ref 1).

The design charts in Appendix C are based on a design method in BS EN1295 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.

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

Bed Type	Description	Surround E Value
S (Drawing Fl)	Granular Surround	5 MPa
T (Drawing Fl)	Sandy Surround	2 MPa
Al1 (Drawing F2)	Filter Drains	5 MPa

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

2.8 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 7) is unity.

Semi rigid and flexible pipe embedments are set out in Table NA8 of BS 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 10 and 9 respectively).

Withdrawal of Trench Supports During Backfilling

2.9 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 should be taken as unity. If the sheeting, or box, is removed in steps after the backfill is compacted then the coefficient should 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 should 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 C. Figures A, B and C of Appendix C 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 (Section 2.2) 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	L	AS
	M	ASB
Thermoplastic		ST

For filter drains the procedure is similar except that the bedding strength provided by all filter drain types shown in the HCD is acceptable (see Section 2.6 (b)). 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 (porous)	Class 1
Precast Concrete (perforated or open jointed)	L
	M
Thermoplastic	Various

It should be noted that in Figures D and E where some group numbers are omitted it is because either the particular class of pipe is not usually manufactured in that diameter or that 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 (Ref 2) 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 of SHW (see Chapter 4).

4. SPECIFICATION REQUIREMENTS

4.1 The Specification for Highway Works (MCHW1 - SHW) 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 should be set out in a schedule which will form part of Appendix 5/1 in Clause 501 of the SHW. An example of a format for this schedule is given in Appendix D.

5. REFERENCES

1. Manual of Contract Documents for Highway Works. The Stationery Office

   (MCHW1) Volume 1: Specification for Highway Works
   (MCHW2) Volume 2: Notes for Guidance on the Specification for Highway Works
   (MCHW3) Volume 3: Highway Construction Details

2. Materials Selection Manual for Sewers, Pumping Mains and Manholes. Water Services Association, London 1993.

3. BD37 Loads for Highway Bridges (DMRB1.3) implementing BS 5400: Part 2. 1978. Specification for Loads. British Standards Institution.

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. 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.

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).

7. A New General Design Method for Buried Flexible Pipes. Mott, Hay and Anderson. (Unpublished TRRL Ref No CON/6102/21).

8. prEN 1046. Plastics piping and ducting systems - Systems Outside Building Structures for the Conveyance of Water or Sewage - Practices for Installation Above and Below Ground. British Standards Institution.

9. BS EN 9967: 1995. Plastics pipes - Determination of Creep Ratio. British Standards Institution.

10. BS EN 9969: 1995. Thermoplastic pipes - Determination of Ring Stiffness. British Standards Institution.

11. BS EN 1295-1: 1998. Structural Design of Buried Pipelines Under Various Conditions of Loading - Part 1: General Requirement. British Standards Institution.

12. BS EN 1610: 1998. Construction and Testing of Drains and Sewers. British Standards Institution.

13. BS EN 598: 1995. Ductile Iron Pipes & Fittings for Sewerage Applications. British Standards Institution.

14. BS 5911: 1992. Precast Concrete Pipes and Ancillary Concrete Products - Part 110: Specification for Ogee Pipes and Fittings (Including Perforated), British Standards Institution.

15. BS 5911: 1992. Precast Concrete Pipes and Ancillary Concrete Products - Part 114: Specification for Porous Pipes, British Standards Institution.

6. ENQUIRIES

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

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APPENDIX A: TYPES OF PIPE TO WHICH CHARTS ARE APPLICABLE

The charts in Appendix C are applicable to the following types of pipe:

a. Vitrified clay pipes to BS EN 295: 1991 to classes L 95, 120, 160 and 200

   BS 65 1991

b. Precast concrete pipes classes L, M and H to the following standards:

   BS 5911: Part 100: 1988
   BS 5911: Part 103: (Prestressed precast concrete)
   BS 5911: Part 110: 1992
   DD 76: Part 2: 1983 (steel fibre reinforced)

c. Thermoplastic pipes to the following standards:

BS 4660	1989 (size 110mm & 160mm diameter)
BS 5481	1977: AMD 3631; AMD 4436 (size 200m diameter and greater)
BS 3505:	1986
BS EN 1401	1998
BS EN 1852	

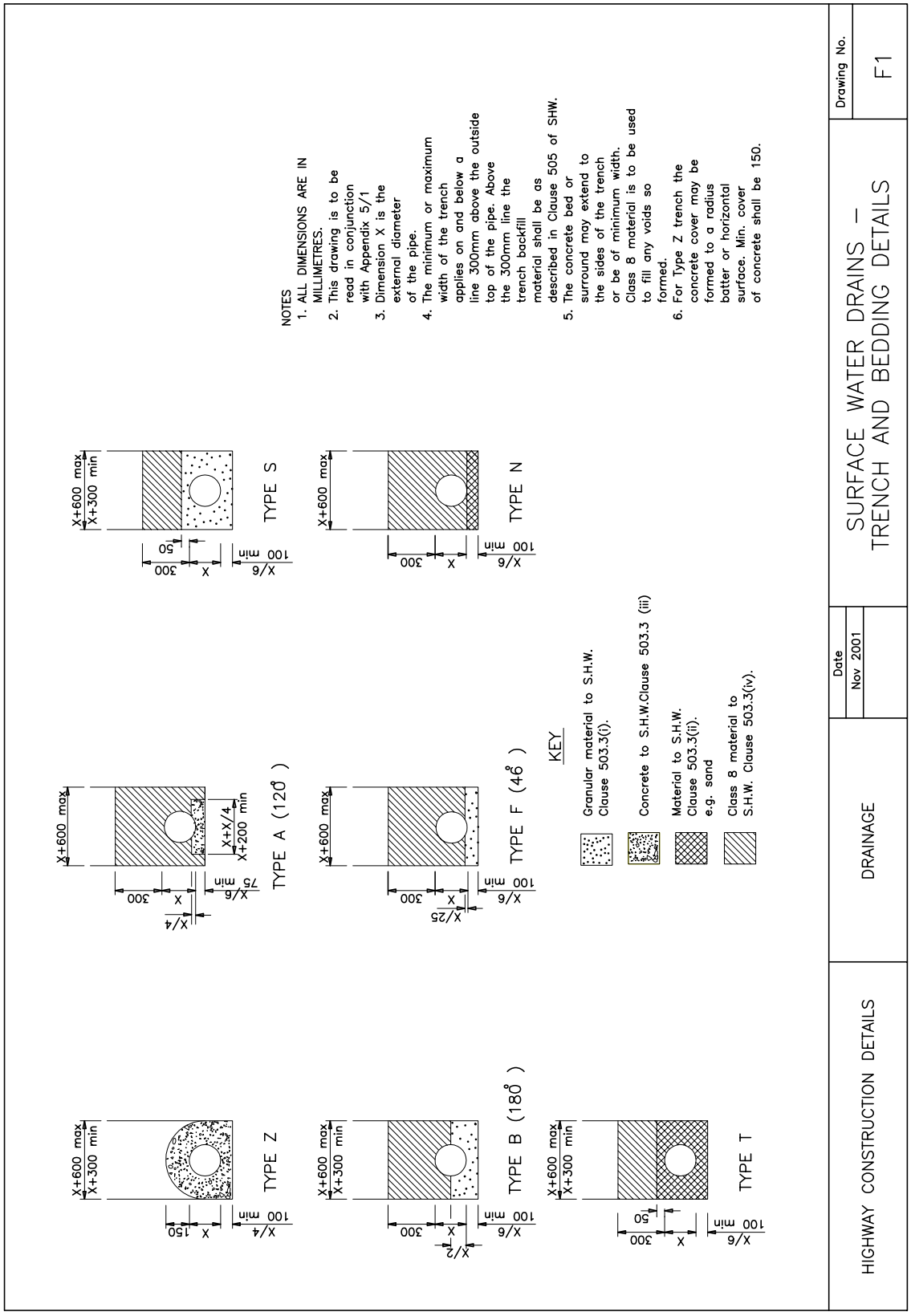
d. Concrete porous pipes:

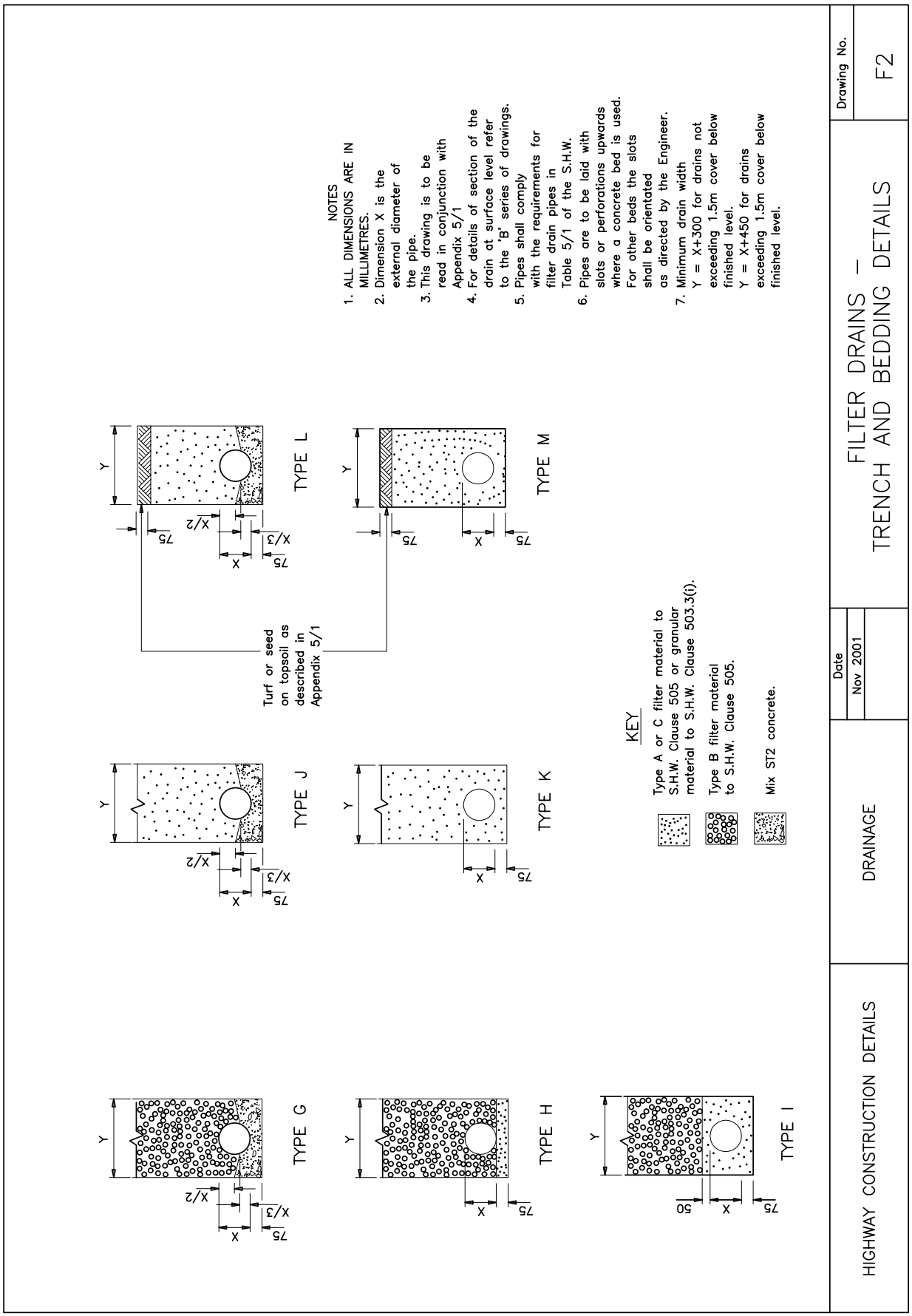
   BS 5911 Part 114: Class 1 and Class 2 for filter drains only.

e. Ductile iron pipes to BS EN 598: 1995
   Cast iron pipes to BS 437.

f. Glass reinforced plastic pipes (GRP) to BS 5480: 1990.

APPENDIX B: HCD DRAWINGS F1 AND F2




NOTES
1. ALL DIMENSIONS ARE IN MILLIMETRES.
2. Dimension X is the external diameter of the pipe.
3. This drawing is to be read in conjunction with Appendix 5/1
4. For details of section of the drain at surface level refer to the 'B' series of drawings.
5. Pipes shall comply with the requirements for filter drain pipes in Table 5/1 of the S.H.W.
6. Pipes are to be laid with slots or perforations upwards where a concrete bed is used. For other beds the slots shall be orientated as directed by the Engineer.
7. Minimum drain width
Y = X+300 for drains not exceeding 1.5m cover below finished level.
Y = X+450 for drains exceeding 1.5m cover below finished level.
KEY
Type A or C filter material to S.H.W. Clause 505 or granular material to S.H.W. Clause 503.3(i).
Type B filter material to S.H.W. Clause 505.
Mix ST2 concrete.
Turf or seed on topsoil as described in Appendix 5/1
TYPE G
TYPE H
TYPE I
TYPE J
TYPE K
TYPE L
TYPE M
HIGHWAY CONSTRUCTION DETAILS
DRAINAGE
Date
Nov 2001
FILTER DRAINS – TRENCH AND BEDDING DETAILS
Drawing No.
F2

APPENDIX C: CHARTS OF BEDDING/PIPE COMBINATIONS

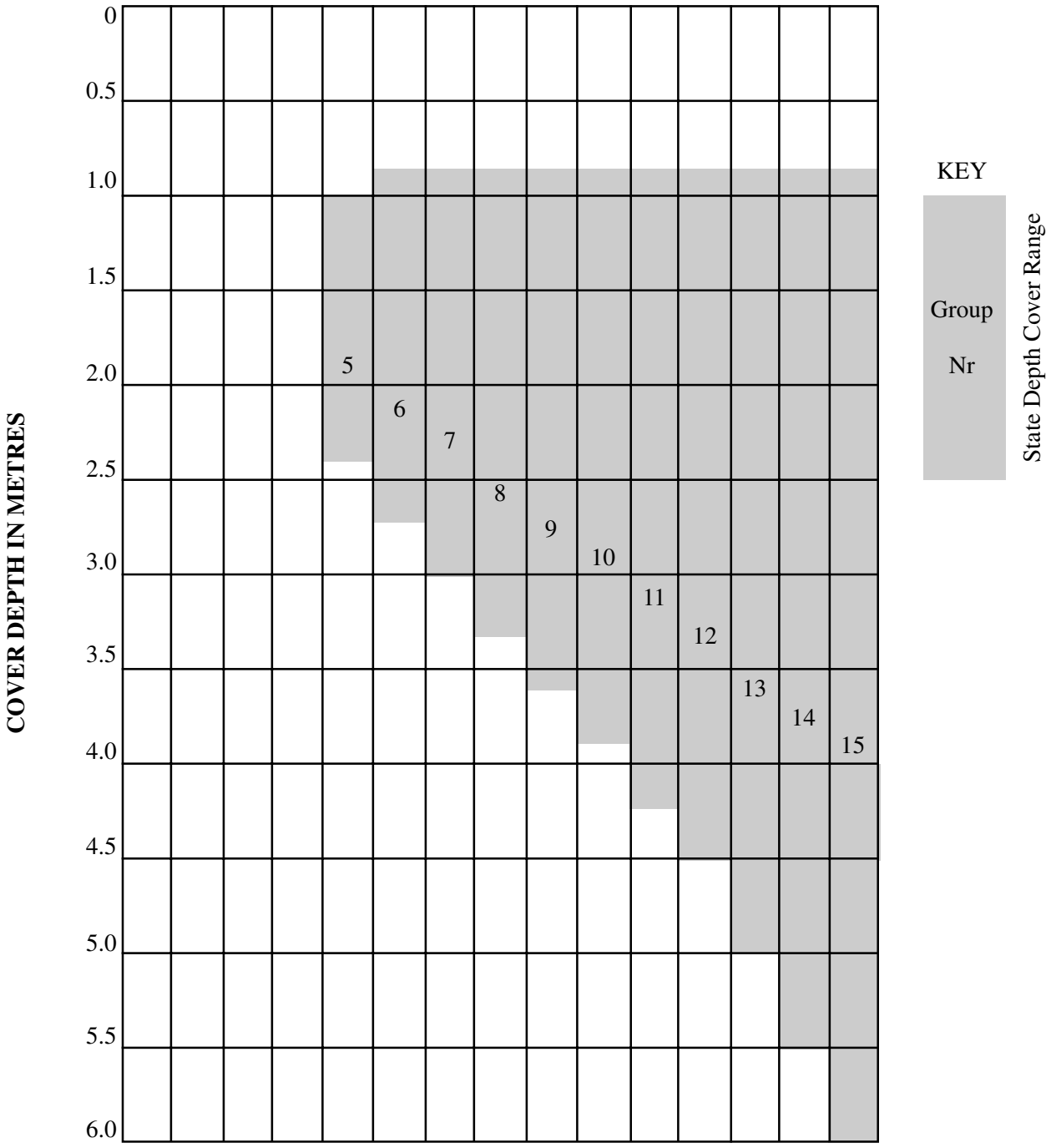


Fig. A - Carrier Drains - Main Road Loading

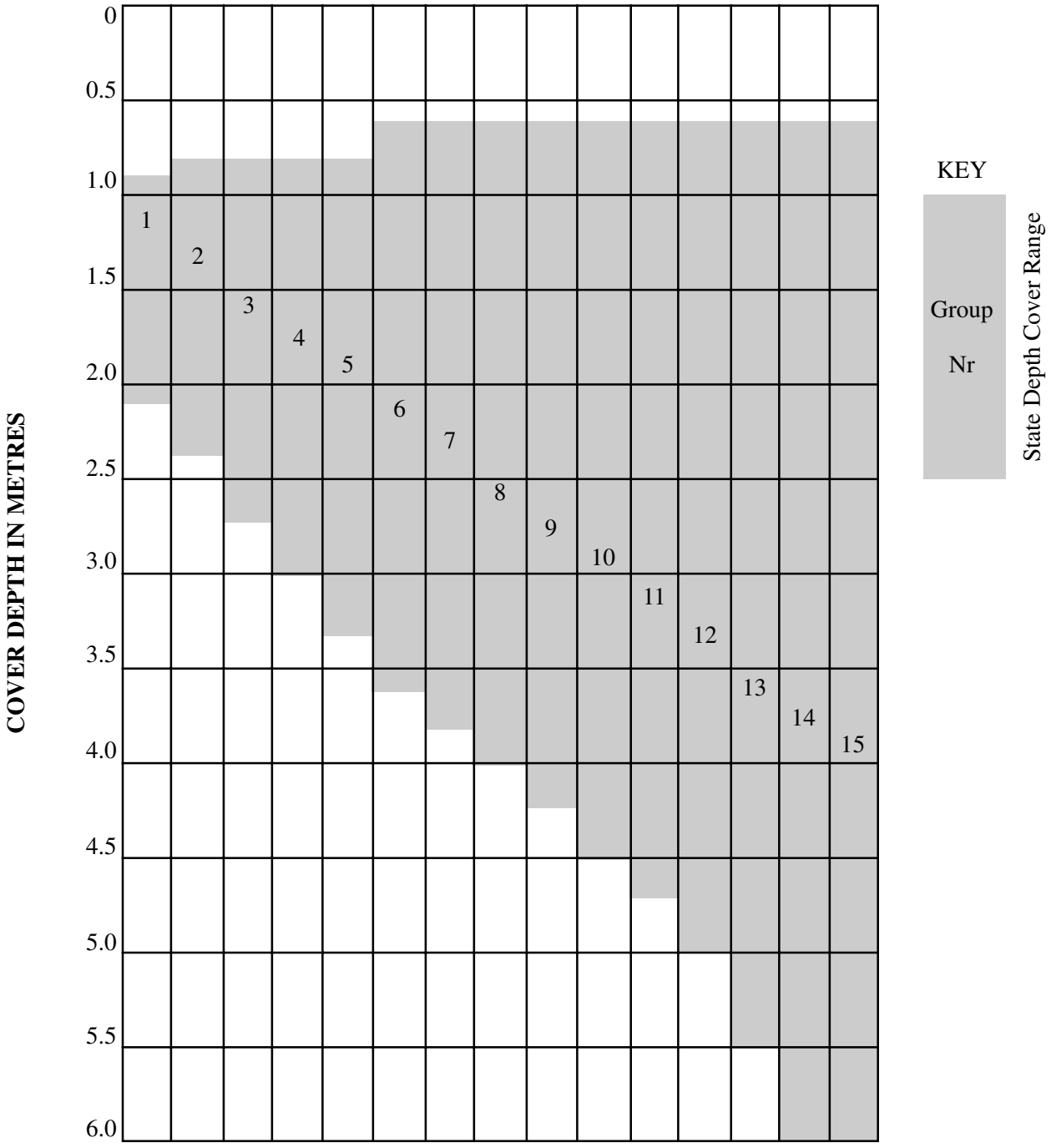


Fig. B - Carrier Drains - Field Loading

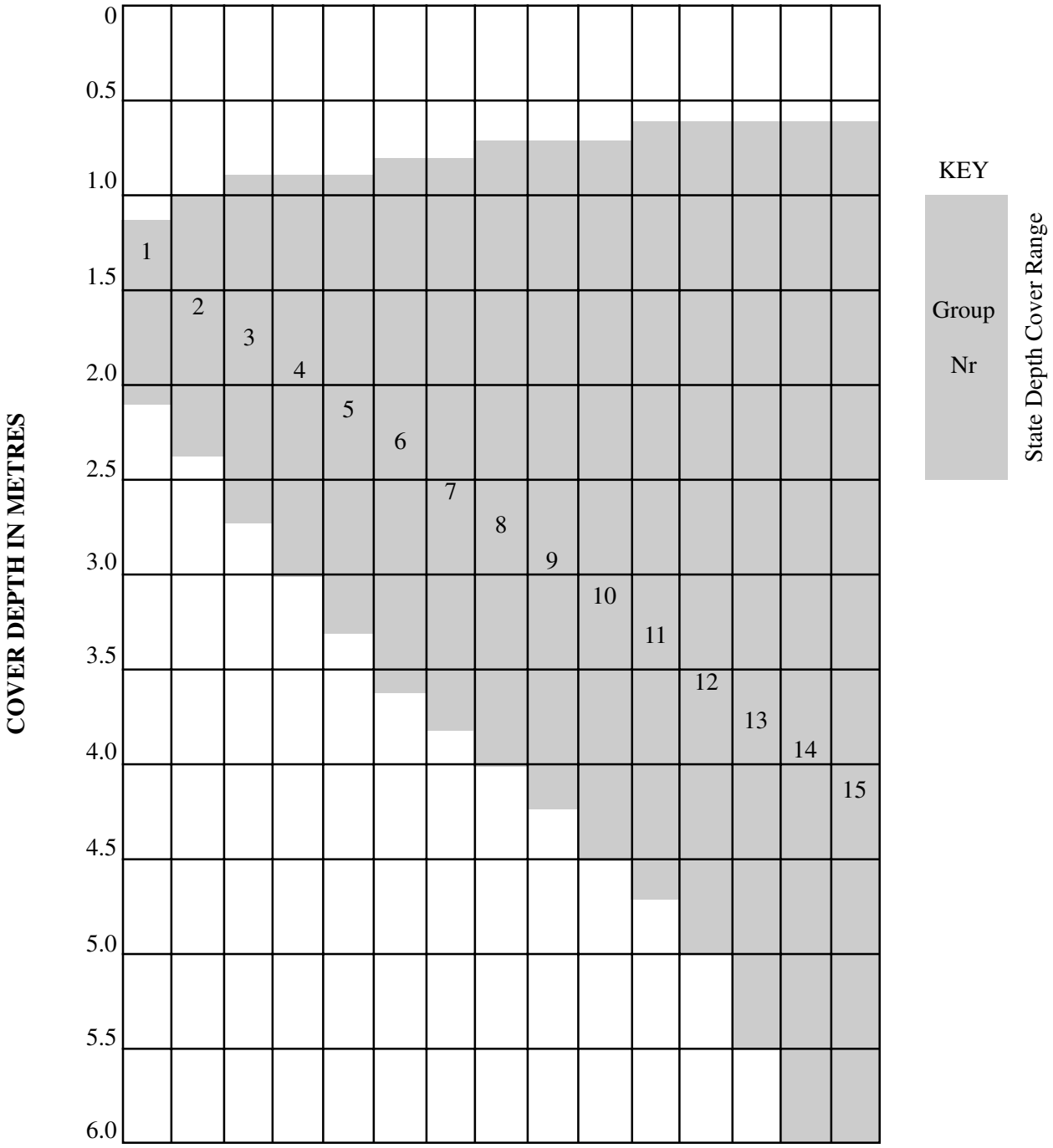


Fig. C - Filter Drains

APPENDIX D: GROUP NUMBERS FOR DETERMINING ALLOWABLE PIPES

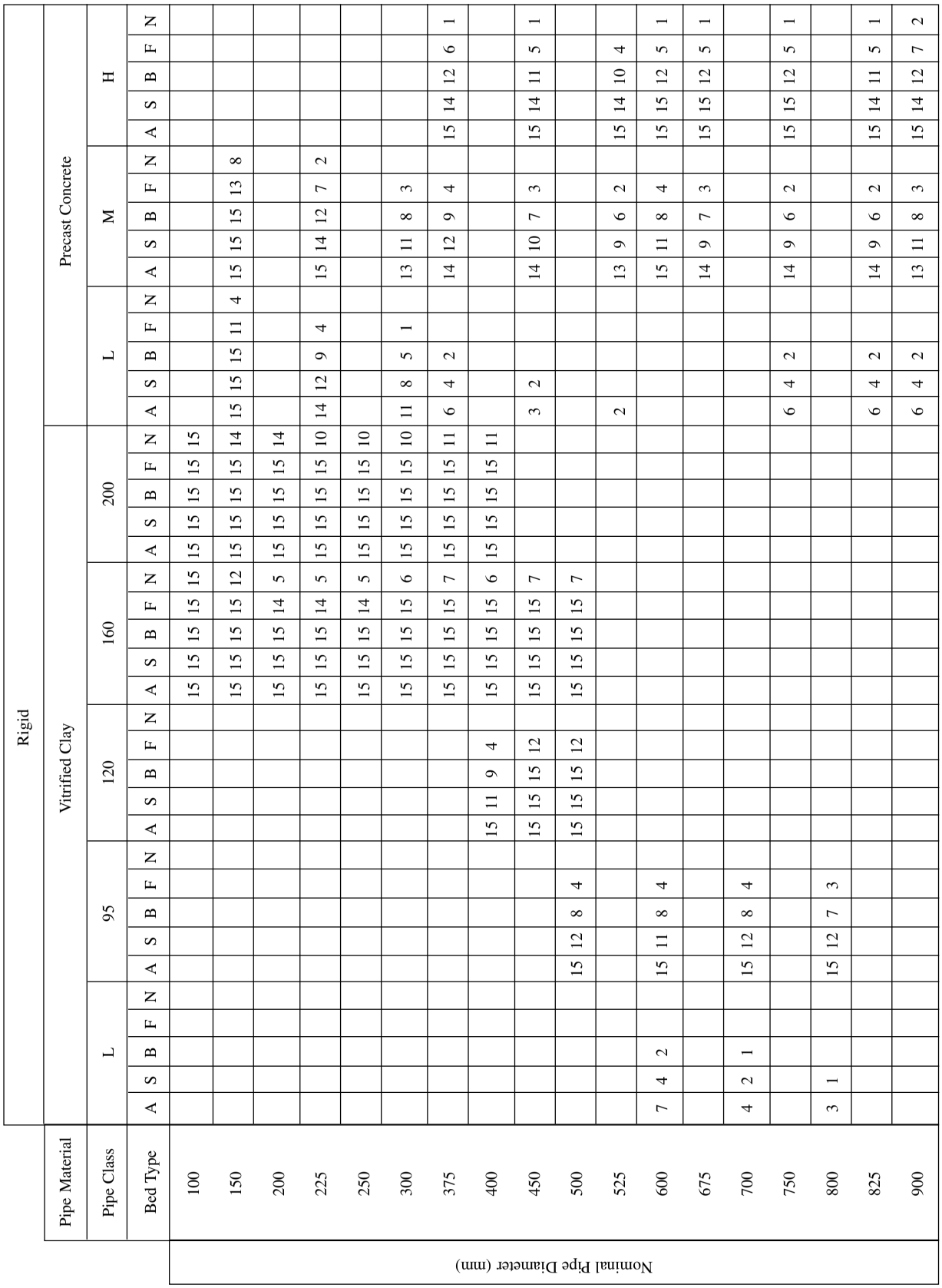


Fig. D.1: Carrier Drains - Group Numbers for Determining Allowable Pipe/Bed Combinations

	Non-Rigid												
	Semi-Rigid						Flexible/Thermoplastic						
Pipe Material	GRP				Ductile Iron		Stiffness > 6KPa				Others by design		
Pipe Class	5 kN/m^2		10 kN/m^2		K9		PVCu		PP/PE		max soil E < 5		
Bed Type	S	T	S	T	S	T	S	T	S	T	4 pvc	8 pe	
Nominal Pipe Diameter (mm)													
100	15		15		15		14	14	12	13	13	14	SDR 41 pipes are specified by external diameter. The nominal diameters shown are the nearest equivalent internal diameter
150	15		15		15		14	13	12	10	13	14	
200	15		15		15		14	10	12	8	13	14	
250	15		15		15		14	10	12	8	13	14	
300	15		15		15		14	9	12	8	13	14	
350	15		15		15		14	9	12	8	13	14	
400	15		15		15		14	9	12	7	13	14	
500	15		15		15		14	9	12	7	13	14	
600	15		15		15		14	7	12	7	13	14	
700	15		15		15		14	7	12	7	13	14	
800	15		15		15		14	7	12	7	13	14	
900	15		15		15		14	7	12	5	13	14	

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

Pipe Material	Vitrified Clay					Precast Concrete				Thermoplastic		
Pipe Class	L	95	120	160	200	L	M	H		Structured Wall	SRD 41	Nominal Pipe Diameter (mm)
Nominal Internal Diameter (mm)												
100				15	15					15		100
150				15	15	15	15			15	15	110
225				15	15	15	15			15		150
250				15	15					15	15	160
300				15	15	4	15			15	15	200
350										15		225
375				15	15		13	15			15	250
400			11	15	15					15		260
450			15	15	15		12	15		15		300
500		12	15	11	15					15		360
525							13	15		15		400
600	4	11		11			13	15		15		450
675							12	15		15		500
700	2	12								15		600
750							12	15		15		700
800		12								15		750
825							12	15		15		900
900							10	15				

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

Pipe Diameter	Pipe Group	Vitrified Clay					Precast Concrete			Ductile Iron	GRP	Thermopastic	
(mm)	No	L	95	120	160	200	L	M	H			Structured Wall	SRD 41
150	2				ASBFN	ASBFN	ASBFN	ASBFN		ST		ST	
160	5												ST
150	5				ASBFN	ASBFN	ASBF	ASBFN		ST		ST	
200	7									ST		ST	ST
225	2				ASBFN	ASBFN	ASBF	ASBFN				ST	
225	7				ASBF	ASBFN	ASB	ASBF				ST	
300	4				ASBFN	ASBFN	ASB	ASB		ST	ST	ST	
400	8			ASB	ASBF	ASBFN				ST	ST	ST	
600	7	A	ASB					ASB	ASB	ST	ST	ST	
750	11							A	ASB			ST	

Carrier Drains

Example of Schedule for Inclusion in Appendix 5/1 of SHW

Drain Type (Lower Trench) Refer to HCD Drawing F2 or Contract Drwg No:	Drain Type (Surface Level) Refer to HCD Drawing B15 or Contract Drwg No:	Pipe Diameter (mm)	Pipe Group Number	Vitrified Clay					Precast Concrete			Thermoplastic	
				L	95	120	160	200	L	M	H	Structured Wall	SDR 41
G, H, I	W	150	4										
M, L	-	225	8										
J, K	Specify in Contract	250	2										

✓ = permitted pipe type

Filter Drains

Example of Schedule for Inclusion in Appendix 5/1 of SHW