NOTES ON PIPE SUBSOIL DRAIN CONSTRUCTION SPECIFICATION

These notes are for guidance and must not be included in the Contract Documents.

Specification TNZ F/2 may be used either independently of, or in conjunction with, the formation specification, TNZ F/1.

1. SCOPE

Water control is the most important factor in highway design and construction.

Although adequate surface drainage is the first step in providing good internal moisture control, a properly designed and installed subsoil drainage system can be essential.

Soil is a material made up of solid particles and various sizes of pores. Water either remains in it or percolates through it. Water retention and movement constitute the two important phases in soil moisture relationship. Water movement takes place by the action of gravity or of capillarity, or by a combination of the two. Subsoil drainage can improve the soil moisture relationship by keeping the ground water-table well beneath the paved surface.

The principal object of all drainage is to facilitate the production of a subgrade of uniform bearing value and strength.

There are four major points, which should be kept clearly in mind when formulating any subsoil drainage installation:

(i) the installation must be related to the particular problem. That is adequate investigation and a proper understanding of the nature of the problem are essential;

(ii) the installation must be specifically designed to meet the problem;

(iii) the drain must be able to pass water without clogging over a long period. That is proper filter material and satisfactory workmanship during installation are essential; and

(iv) the drain must be able to support any superimposed loading. The quality of the pipes should be specifically checked before their use is accepted.

Subsoil drains should not be expected to transmit large flows of water. The drainage of springs for example is best catered for by a sealed pipe.

Piped subsoil drains should not be used or designed to drain surface water.

Subsoil drains can be divided into three main types:

(i) Traditional standard subsoil drain placed at least 1 m below the finished subgrade level to maintain a lower ground water-table. (See Fig 1).

Deep drains are more effective than shallow drains in maintaining a low ground water-table. While this is as true in heavy clay soils as in the more permeable materials, the area of significantly lowered ground water level for heavy clay soils is only in the immediate vicinity of the drain trench.

Although properly placed subsoil drains can maintain a lower ground water-table and control the capillary rise, they will not completely eliminate the upward movement of moisture in all soils. On certain subgrades it is essential to place a sand or other grandular sub-base course in order to intercept and remove capillary moisture as fast as it accumulates.

Provision should normally be made for the section of the sub-base course located below the sealed pavement to drain into the backfill of subsoil drains.

(ii) Interceptor drains. (See Fig 2).

These are used in the situation where water seeps along a layer of impervious material towards the road formation. Interceptor drains are placed to intercept and drain away this water before it reaches the formation. The most common use of interceptor drains is in cuttings and sidlings.

(iii) Pavement drains. (See Fig 3).

These drains are actually placed within the road metal, so that they directly drain the basecourse and sub-base layers. (Unlike type (i) which relies primarily on lowering the water-table in the subgrade). Because these drains are laid relatively close to the pavement surface superimposed wheel loading relative to pipe strength becomes an important consideration.

Small diameter plastic pipes are often used in pavement drains.

Pavement drains will frequently be used where kerb and channelling is installed.

There are several other types of subsoil drains which are not dealt with in NRB F/2, in particular:

(i) Slotted, corrugated plastic pipe drains. Refer to TNZ F/5 "Subsoil Drain Construction Using Corrugated Plastic Pipe".

(ii) French drains. These consist of a trench filled with open graded granular material (which allows a relatively free flow of water).

Anti-clog french drains. These are a french drain with the open graded granular material wrapped in filter fabric. The filter fabric acts as a base on which a filter cake forms between the granular material and the surrounding soil. Refer to NRB F/6 "Fabric Wrapped Aggregate Subsoil Drain Construction".

The water carrying capacity of french drains can be increased by installing a perforated pipe within the open graded granular material.

(iii) Pipe subsoil drains where the pipes are enveloped in a filter fabric sock which replaces the usual filter material.

With this type flow into the pipe can be restricted by head losses in the soil surrounding the pipe. For this reason use would normally be limited to subsoil drains in some types of sand.

2. MATERIALS

In general for subsoil drain pipes (usually from 100 to 400 mm diameter) the structural design need not be considered from first principles, but pipes simply picked from loading charts. However, in cases involving low cover depths with heavy superimposed traffic loadings or large cover depths, their structural design should be considered in detail.

Pipes laid underground can be classified into two types, rigid or flexible, according to their structural behaviour.

(i) Rigid pipes (Ceramic, and concrete pipes). The following code of practice is recommended for the calculation of loads on rigid pipes:

NZS 4451:1974 "Loads on Buried Rigid Pipes" Amendment A 1974 (which is AS CA33-1962, "Concrete Pipe Laying Design"). This code sets out a recommended design practice for calculating installation requirements for the laying of precast concrete drainage pipes. It includes methods for calculating loads on pipes according to a range of installation conditions, and gives the corresponding load factors. It provides for vertical loads due to fill material, superimposed static uniformly distributed loads and superimposed concentrated loads.

Chapter 7 "Structural Design of Pipe Culverts" of CDP 706/A August 1978 Culvert Manual is based on this code. In general the Culvert Manual does not consider pipes with a diameter less than 375 mm.

(ii) Flexible pipes. (Plastic pipes)

The following code of practice is recommended for the calculation of loads on flexible pipes:

AS/NZS 2566 : 1998 Buried flexible pipelines – structural design

This Standard sets out a practice for the structural design of buried flexible pipelines.

It includes methods for calculating loads. safe bedding depths and reflections under a range of laying conditions. (Applies to PVC and polyethylene pipes).

The laying of pipes in general is covered by AS 2032:1977 “Installation of uPVC pipe systems”, and AS 2033 “Installation of Polyethylene pipe systems”

2.1 Pipe Types

The type of pipes to be used on the contract shall be selected by the engineer from one of the categories outlined in specification TNZ F/2 and indicated on the drawings.

2.1.1 Ceramic pipes

NZS 1823:1967 (Imperial units) states:

Ceramic pipes are manufactured by moulding clay into pipe and subjecting to suitable temperatures (firing) to make them strong and durable.

That pipe barrel lengths be a minimum of 2 feet (600mm) and a maximum of 5 feet (1500mm).

That nominal diameters vary from 4 inches (100mm) to 15 inches (375mm) with corresponding wall thicknesses varying from 0.5 inch (12mm) to 1.25 inch (32mm).

That the minimum crushing strength be 2250 lb per linear foot (approximately 33 kN/m). When subjected to this load no pipe shall crack.

That pipes be tested to ensure that their permeability is no greater than a specified maximum.

That pipes can be glazed or unglazed or partially internally glazed as agreed between manufacturer and purchaser.

Availability varies from place to place. An example range from one manufacturer is:

Internal diameters; 100, 150, 225 and 300 mm

Pipe lengths; all 1250 mm

Joints; Rubber ring joints available for 100, 150, 225 and 300 mm diameters. Rubber sleeve joints available for 100 and 150 diameters.

These pipes exceed the strength requirements of NZS 1823:1967 and in fact exceed the crushing strength required of class Z concrete pipes.

Minimum cover depths (for operation under wheel loads without special protection) recommended by the manufacturer are:

INTERNAL DIAMETER (mm)	MINIMUM COVER DEPTH (mm)
100 - 150	500
225 - 300	1000

Ceramic pipes are unaffected by all types of ground water and micro-organisms.

2.1.2 Unreinforced concrete pipes

NZS 3107:1978 Class C pipes shall not crack under the following proof loads:

INTERNAL DIAMETER (mm)	PROOF LOAD (kN/m)
100	19
153	19
200	19
300	22
400	28

In general pipes available considerably exceed the above strength requirements. One manufacturer's unreinforced concrete pipes are as strong as class Y reinforced concrete pipes. Hence they require a minimum cover depth under highway loading or approximately 600 mm.

These pipes are available in lengths of 1200 mm and nominal diameters of 150, 225 and 300.

2.1.3 Reinforced concrete pipes

NZS 3107:1978 sets the following minimum proof and ultimate loads:

INTERNAL DIAMETER (mm)	PROOF LOAD (kN/m)	ULTIMATE LOAD (kN/m)
	Class S (Y)	Class S (Y)
100	10 (19)	15 (28)
150	10 (19)	15 (28)
200	11 (19)	16 (28)
300	12 (22)	18 (33)
400	14 (27)	20 (40)
-	-	-
2400	41 (115)	61

Class X, Y and Z pipes are stronger than class S pipes

Under the appropriate proof load a pipe shall not develop a clearly visible crack (but may develop minor cracks). Under the appropriate ultimate load pipe may crack extensively but shall not distort more than 10% of the nominal diameter.

The joints should be specified by the purchaser.

Minimum cover depths under highway loading are tabulated below:

INTERNAL DIAMETER (mm)	APPROXIMATE MINIMUM COVER DEPTH UNDER HN-HO-72 LOADING (mm)			
	Class			
	S	X	Y	Z
150	800	650	400	300
225	1400	750	500	400
300	*	900	600	400
375	*	1000	600	400
450	*	1000	600	400
525	*	1000	600	400

* This installation is inadequate to support the design loading under any fill height.

2.1.4 Clause deleted

2.1.5 Corrugated steel pipes

Pipes covered by this standard are not manufactured in New Zealand at present.

2.1.6 Nestable corrugated steel pipes

These pipes become more competitive when transport distances become significant, especially with the larger diameter pipes.

NOMINAL DIAMETER (mm)	MINIMUM COVER (mm)
200	300
300	300
400	300

For full list of diameters available and maximum and minimum cover depths see appendix A of chapter 18 of the Culvert Manual.

2.1.7 PVC pipes

These are the type commonly used for domestic drain, waste and vent systems colour coded light grey. These pipes can be solvent welded or use elastomeric sealing ring joints.

2.1.8 High Density Polyethylene Pipes

NZS 7604:1981 mentions pipes with a nominal internal diameter of from 80 mm to 225 mm. Pipes are classified in terms of nominal internal diameter but are dimensioned and standardised on outside diameter and wall thickness.

Dimensioning is based on the diametral deflection of the pipe due to vertical external loading and must not exceed 5% - 7% of the outside diameter over 50 years.

Performance of a pipe in service is likely to be impaired if the depth of a scratch exceeds 20% of the wall thickness, or if a surface abrasion exceeds 10% of the wall thickness and extends over more than 3% of the circumference of the pipe.

Three classes of pipe:

(a) Light wall (SDR = 32)

(b) Medium wall (SDR = 25)

(c) Heavy wall (SDR = 15)

where SDR (standard dimension ratio)= $\frac{\text{Maximum mean outside diameter}}{\text{Minimum wall thickness}}$

Restrictions on use:

Situations requiring the use of medium and heavy wall pipe should be the subject of deliberate engineering consideration, and reference made to the pipe manufacturer for detailed information on such applications.

For many situations light wall pipe will be suitable, and the following comments should be used for guidance on installation.

Ceramic, concrete and other rigid pipes support vertical loads without deformation mainly by the ability of their walls to resist circumferential bending. Polyethylene, or PVC being flexible, can utilise the backfill material to support a large portion of the imposed load, by deflecting a small amount.
Thorough compaction of selected backfill against the sides of either rigid or flexible the pipe is vital to the integrity of the pipe system.

Recommended minimum depths of cover (NZS 7604:1981, appendix B) unless pipe protected from backfill and superimposed load (for example by encasing in concrete) are as follows:

	MINIMUM COVER (mm)
Sealed Roads	600
Embankment conditions/construction equipment loading	750
Unsealed roads	750
Not in roadways	450
Not subject to vehicular loading	300

These requirements are as per the following standards AS/NZS 2566; AS 2032; AS 2033

The use of unprotected pipe is not recommended at cover depths exceeding 4 m, nor at any depth under a road or street that may be used as a route for overweight movements involving axle loads greater than 1.5 times class I loads.

2.2 Joints

The specification has been written to preclude rigid joints.

2.3 Filter material

In nearly all installations, the same material is used in contact with the trench walls and pipe holes. Clearly the properties required to act satisfactorily against the trenched soil are dependent upon the soil. The stock graduation is designed to be a "universal" filter and there are very few soil/pipe combinations for which it is not appropriate.

However, when the Engineer considers that the stock F/2 aggregate is not suitable, the granular filter should be specially designed as to be explained shortly.

Note however that in the majority of cases satisfactory alternative materials that are substantially cheaper than the stock mix will be available. As a start point, all in 'builders mix' and similar clay free, well sanded gradings available locally should be examined. In specifying variant gradings tolerances should only be set as tightly as are needed by the soil to be protected.

For a protected soil requiring special considerations, care should be taken to minimise the problems and expense of obtaining alternative non-standard gradings from local quarries.

Filter materials should be selected and graded to comply with a number of rules. The terminology adopted for the presentation of the rules is as follows. d (mm) is used when defining d filter material particle size. D (mm) is used when defining a protected soil particle size. A numerical subscript xx refers to the percentage by mass of particles less than the size d or D as the case may be.

The symbol u denotes the coefficient of uniformity of the filter material; ie, $u = d_{60}/d_{10}$. The symbol U denotes the coefficient of uniformity of the protected soil; ie, $U = D_{60}/D_{10}$.

The rules are:

(a) $d_{15} < 5\ D_{85}$

(b) $d_{15} > 5\ D_{15}$

(c) $d_{15} < 40\ D_{15}$, except when $U < 4$, in which case $d_{15} < 20\ D_{15}$

(d) $d_{15} > 0.2$ mm

(e) $d_{50} < 25\ D_{50}$; this rule may be disregarded for clay soils, but the filter must be well graded, and satisfy $u < 20$ to avoid segregation.

(f) d_{85} > 1 x hole diameter in pipes, this rule may be disregarded if the pipe is enclosed in a filter fabric.

Rule (a) has the purpose of resisting the piping of fine soil particles through the filter. Rules (b) and (d) ensure that the permeability of the filter is adequate. Rules (a) and (b) are the most important, and stem from early experiments carried out by Terzaghi and by the US Waterways Experimental Station. Rule (e) is sometimes called a "uniformity" condition: it ensures that the grading envelopes of filter and soil do not depart too much from being parallel. Rule (c) is present in some references only, and is perhaps a further uniformity condition. Uniformity conditions have a bearing on both piping and permeability.

When the protected soil contains a large percentage of gravels, the filter should be designed on the basis of the gradation curve of the portion of the soil which is finer than 19.0 mm.

The method of design for filter materials is explained in article 17.32, page 334 of the Department of Scientific and Industrial Research, London, publication "Soil Mechanics for Road Engineers" but the above slightly modified criteria shall be used. Another excellent reference is "Seepage, Drainage and Flow Nets" by H R Cedergren (Wiley), pages 175-181. This book lists several references. A worked example of granular filter design appears as appendix 2 of these notes.

3. EXCAVATION

For a trench installation the load which reaches the pipe is less than the weight of the fill material above the pipe (plus traffic load) because of the friction between the fill material and he sides of the trench. The frictional resistance diminishes with increase in trench width at the level of the top of the pipe. So the width of the trench should not exceed the specified dimensions as this could increase the loading on the pipe.

Thus the narrower the trench and the nearer the sides of the trench approach the vertical (in particular from the trench bottom to 300 mm above the top of the pipe), the greater the load the pipe will support.

It should also be appreciated that the trench must be wide enough to enable the pipes to be properly laid. For rigid pipes a trench width of one diameter plus 300 mm is usually recommended.

The sides from 300 mm above the top of the pipe to the surface may diverge if desired, using either a smooth divergence with side slopes of to one or steeper, or a stepped divergence giving the same trench width at the top.

4. BEDDING

In general the effective life of a pipeline depends very largely on the uniformity of support and absence of point loads. Non-uniform support can be due to hard spots or localised settlement in the foundations. The purpose of bedding is to ensure uniform longitudinal support to the pipe and also to provide lateral support.

However, for pipe subsoil drains, unless laid with minimum cover, the bedding is not usually critical because the shallow depths subsoil drains are laid at means there is often a considerable reserve of pipe strength available. Consequently the cheapest and most practical bedding is used. Often this is best achieved by bedding on a minimum thickness of compacted filter material.

(a) Bedding on clay. The barrel is supported on compacted filter material with the joints having little or no filter material under them.

(b) Bedding on rock. Using approximately 40 mm thickness of compacted filter material under the joints and a matching greater thickness under the barrel to ensure the pipe is supported for the full length of the barrel.

If bedding design is warranted for a particular pipe then the various bedding types and associated pipe structural design are comprehensively dealt with in chapter 7 of the Culvert Manual.

5. BACKFILLING

Bearing in mind the need to relate subsoil drainage to the peculiar factors applying in each specific installation, the usual "standard" backfilling details can not always be applied, in which case, the necessary modifications should be shown on the plans, or detailed in the job specification.

6. OUTLETS

Open subsoil drain outlets should be constructed on a relatively steep grade to ensure unimpeded pipe discharge. The outlets should be located so that flooding of adjacent water course; does not sub-merge the outlets. The outlets should be located so that they will remain clear and be marked so as to be easily found for maintenance inspection under all normal circumstances.

In many situations the outlet pipe(s) may be non-perforated and not surrounded with filter metal.

Outlets should be provided whenever there is discharge opportunity. This reduces uninterrupted subsoil drain length.

7. MAINTENANCE

If subsoil drainage construction is let in conjunction *with* other contracts, eg, formation, basecourse construction and sealing, the expiry date for the maintenance period should be the same as that fixed for the entire works.

On the other hand, should subsoil drainage construction be advertised as a contract independent of other construction contracts, the date fixed for the termination of the maintenance period should be some time after the winter following the completion of the sub-soil drainage system.

8. BASIS OF PAYMENT

No separate payment is made for maintenance.

The Contract Schedule should be compiled from appropriate items worded in the following manner:

ITEM	DESCRIPTION	UNIT
I	Subsoil drains installed at various depths	
(i)	100 mm diameter pipe installed at depths 1.0 to 1.5 metres	metres
(ii)	100 mm diameter pipe installed at depths in excess of 1.5 metres	metres
(iii)	150 mm diameter pipe installed at depths 1 to 1.5 metres	metres

APPENDIX 1
TYPICAL SECTIONS OF SUBSOIL DRAIN INSTALLATIONS

FIG. 1

Standard longitudinal drain where the objective is to control ground water-table level

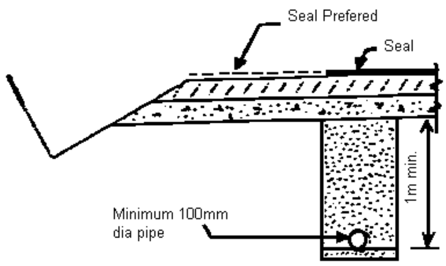


FIG. 2

Interceptor drain where the objectrive is to intercept water seeping along a rock surface under a clay overburden

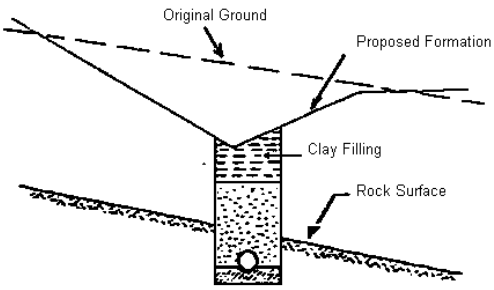


FIG. 3

Trenchless Pavement Drain where objective is to directly drain basecourse and sub-base

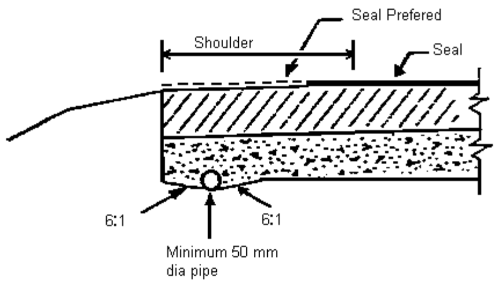
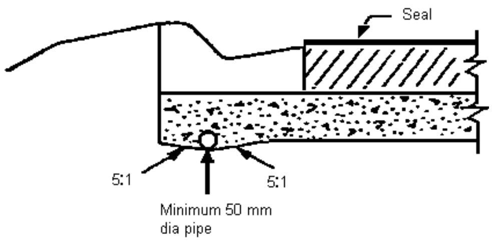
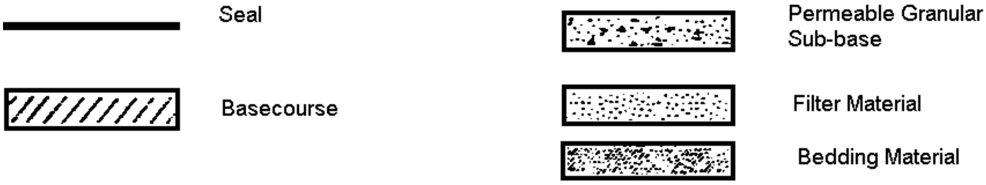


FIG. 4

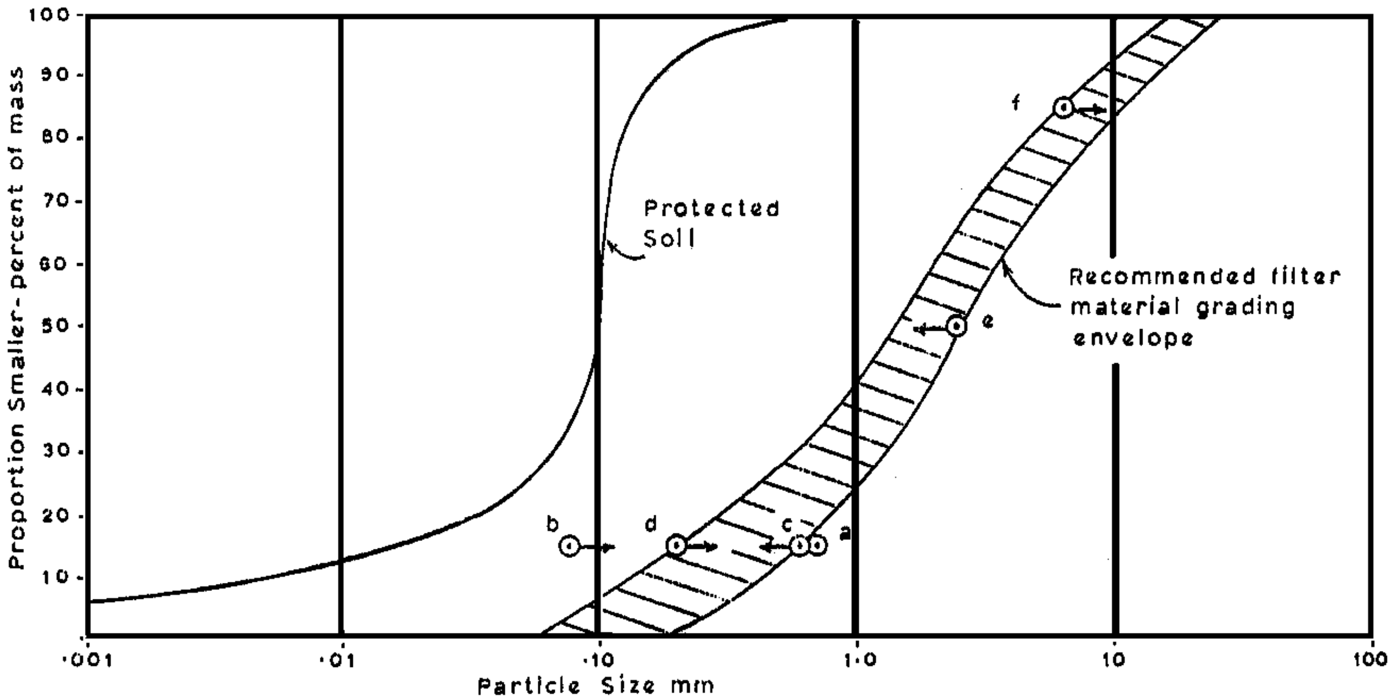
Trenchless Pavement Drain under kerb and channel. Objective is to directly drain basecourse and sub-base



LEGEND



APPENDIX 2
Example of Granular Filter Design



Note
Refer to Section 2·3 for discussion and notation.
D_{15} etc, refer to protected soil.
d_{15} etc, refer to granular filter

Protected Soil Particle Size
$D_{15} = 0{\cdot}015$ mm
$D_{50} = 0{\cdot}10$ mm
$D_{85} = 0{\cdot}14$ mm

Filter Grading Criteria

a : $\frac{d_{15}}{D_{85}} \leq 5$ c : $\frac{d_{15}}{D_{15}} \leq 40$ e : $\frac{d_{50}}{D_{50}} \leq 25$

b : $\frac{d_{15}}{D_{15}} \geq 5$ d : $d_{15} \geq 0{\cdot}2$ mm f : $d_{85} \geq 6{\cdot}5$ mm (Pipe hole dia)