Backfill Specification

MRWA Specification 04-03.2

Melbourne Retail Water Agencies
(Including City West Water, South East Water & Yarra Valley Water)

Revision Date: 2013

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Please note that MRWA Specification No 04-03 or information contained within the Specification must only be used in conjunction with the Melbourne Retail Water Agencies Editions of the WSAA Water Supply Code of Australia (WSA 03) and WSAA Sewerage Code of Australia (WSA 02) and AS2566.2: Buried Flexible Pipelines: Part 2- Installation.

Please Note: This Specification may be periodically updated.

1 INTRODUCTION

1.1 Application

This Specification sets out the Water Agency's requirements for the backfill and compaction of soils in excavations associated with the construction of water supply and sewerage (pressure and non pressure) assets. This specification refers to the trenchfill zone and not the embedment zone. For details of embedment zone requirements, refer to the MRWA Edition of the WSAA Water Supply and Sewerage Codes.

It also applies to fill associated with assets constructed in tunnels, drives, shafts and bores.

1.2 Exclusions

Backfill in trafficable areas shall be completed in accordance with the road owner's requirements and these requirements generally take precedence over this specification (refer to Section 3).

Backfill within areas that contain thick compressible clays (Coode Island Silt) and Acid Sulphate soils are outside the scope of this Specification. Projects which are to be undertaken in areas that contain such soils require a site specific geotechnical review and a backfill design which takes into account the findings of such a review.

1.3 Responsibility for Subsidence

Where it is established beyond reasonable doubt that subsidence has occurred due to work undertaken by the Contractor, the Contractor shall make good any damage caused as a consequence of subsidence, including (but not limited to) other authority assets, fences, buildings, paving and/or landscaping works. "Damage" is deemed to include tilting or leaning structures.

As the behaviour of backfill material is moisture and therefore weather dependant, problems with backfill density may only appear after protracted periods of intense weather. Such events may take many years to occur. As such, when subsidence occurs due to inadequate trench compaction, the Contractor may be held accountable for correcting the subsidence many years after the construction has been completed.

1.4 Requirements for this Specification

Correct trench backfill and compaction is a critical success factor for the projects requiring backfill. Incorrect backfill and compaction by contractors causes the Water Agency to incur risks associated with backfill subsidence and collapse such as:

- Customer inconvenience and dissatisfaction.
- Damage to customer and council assets.
- Damage to other authorities' infrastructure.
- Hazards to road users and pedestrians.
- Costs associated with rectifying damage.
- Costs associated with litigation for damages.

Compliance with this Specification will reduce or eliminate these risks by assisting contractors to:

- Understand that soils are like any other construction material. Different soil types have differing properties, and require different construction techniques to ensure optimum performance.
- Comply with a basic standard of backfill and compaction appropriate to each soil type.

1.5 Relevant Australian Standards

AS 1289:	Methods of Testing Soils for Engineering Purposes.
AS 3798:	Guidelines on Earthworks for Commercial and Residential Developments.
AS 2566.2:	Buried Flexible Pipelines: Part 2 - Installation.
As 2870.2	Residential Slabs and Footings

1.6 Definitions

For the purpose of this specification, the following definitions shall apply:

Aggregates:

Granular materials used in construction, including sand, gravel, crushed stone, slag, or recycled crushed concrete.

Approved, Approval:

Unless otherwise specified, means approved by, or approval of, the Superintendent or the Water Agency.

Average Horizontal Bearing Pressure (AHBP):

The maximum average contact pressure on soil which will not produce shear failure of the soil.

Backfill, Fill, Trenchfill:

Terms used to describe the material used in the Trench Fill Zones.

Clay or Clayey Soil:

Soil which has a plasticity index > 20 and contains a high fraction of phyllosilicate mineral particles which are less than 2 micrometres in size.

Compaction:

The process whereby the density of a soil mass is increased by mechanical, usually dynamic, means. This typically involves tamping, rolling, or vibration, or a combination of these processes. This results in a relocation of soil particles and the expulsion of air from the soil mass, but usually without significantly altering the amount of water in the soil.

Cohesionless Soils:

Poorly graded sand and gravel mixtures, generally with less than 5% fines (ie finer than 75 µm), which are non-plastic and which do not exhibit a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1. These will typically be “clean sands”.

Cohesive Soils:

Those materials which have a well-defined moisture-density relationship when tested in accordance with AS 1289.5.1.1 or AS 1289.5.2.1. Cohesive soils are typically clayey in nature.

Settlement:

Reduction on the volume of soil which usually leads to a decrease in surface level.

Constructor / Contractor:

An individual, corporation or legal entity including any contractor and sub-contractor that is accountable at law for delivery of works under a specific contract or development agreement / deed.

Crushed Rock:

Rock which is free of organic material which has been mechanically broken down to a predetermined particle size distribution.

DCP:

Dynamic Cone Penetrometer. Measures soil strength attributes and compaction. Refer to AS2566.2 for details.

Design:

Design is the creation of a plan for the construction of an object or a system.

Dry Density Ratio, Relative Compaction:

The degree of compaction specified and achieved in cohesive soils is usually expressed as a dry density ratio, as described in AS 1289.5.4.1. This compares the dry density of the compacted soil with a reference density, being the peak dry density which can be achieved in a controlled laboratory compaction process, e.g. Standard Compaction, AS 1289.5.1.1. Dry Density Ratio is also sometimes referred to as Relative Compaction. This more generic term allows for other reference testing procedures such as Hilf Rapid Compaction (AS 1289.5.7.1) for clay fills and Density Index (AS 1289.5.6.1) for sands.

Embedment Zone, Trench Fill Zone:

The areas defined in MRWA Editions of WSAA Water Supply and Sewerage Codes: Standard Drawings.

Field Density Testing:

To allow comparison of the achieved field compaction with a laboratory reference density, it is necessary to be able to reliably determine the achieved field density and moisture content. The commonly used methods for assessing field bulk density is the nuclear density gauge (AS 1289.5.8.1), but moisture content usually is measured in the laboratory.

Indirect measures of achieved compaction include penetrometer testing. The Perth Sand Penetrometer (PSP) is often used in clean sands, with the number of blows required to drive a blunt ended rod into the sand taken as an indicator of the relative compaction of the sands (see PSP). The Dynamic Cone Penetrometer (DCP) provides a similar correlation for all soil types.

Granular Material:

A granular material is a conglomeration of discrete solid, macroscopic particles (grains) which have relatively free movement with respect to each other. Visible air voids cannot be produced within granular material. When stockpiled, granular material will not be able to have an angle of repose greater than 30 degrees. Particles which tend to bond together (colloidal or clay particles) are not considered granular. The lower size limit for grains in granular material is typically 2 µm.

Maintenance Structure:

Any structure designed to enable maintenance; eg: Inspection Shaft, Maintenance Shaft, Maintenance Chamber or Maintenance Hole.

Maximum Dry Density, Optimum Moisture Content:

The peak dry density achieved in the laboratory compaction test is referred to as the Maximum Dry Density (MDD), and this occurs at the relevant Optimum Moisture Content (OMC) for that compactive effort. The MDD and OMC derived in the laboratory test are not unique properties of a soil, but are dependent upon the applied compactive effort and the nature of this effort. In the laboratory, there are Standard (AS 1289.5.1.1) and Modified (AS 1289.5.2.1) efforts. Modified compaction applies approximately 4.5 times the energy of Standard compaction. Similarly, in the field, different compaction equipment will apply different compactive effort.

Moisture Conditioning:

Although the moisture content of a soil mass usually is not significantly altered by the compaction process, the degree of compaction (density increase) which can be achieved for a given compaction effort is dependent upon the moisture content of the soil being compacted. The alteration of the moisture content prior to compaction is often referred to as moisture conditioning.

Nature Strip:

Unpaved part of the road reserve which is typically has garden, grass or soil on the top surface.

Non Trafficable Area:

Areas other than those defined as Trafficable.

Ordinary Fill:

Material obtained from excavation or imported that contains not more than 20% by mass of rock fragments with size between 75 mm and 150 mm, with no rock or clay fragments greater than 150 mm. (Refer AS 2566.2-2002.)

Reactive Soils:

Clay soils, for which a change in moisture content may result in sufficient change in volume to affect the engineering performances of any structure (including pavements) influenced by this soil. (Refer AS 2870.2- 2011).

Road Authority:

The authority that is responsible for the care and management of the road reserve in question.

Road Reserve:

The public carriageway reserve between property boundaries which contains assets including, but not limited to, the road formation, footpaths, driveways, nature strips.

Selected Fill:

Material that is free from organic or other deleterious material, obtained from excavation or imported, with a particle size for rock not greater than 20 mm, or for other than rock not greater than 75 mm. (Refer AS 2566.2-2002.)

Settlement:

Settlement is a downwards displacement of the ground surface, relative to either the surrounding ground (differential settlement) or a stable bench mark (total settlement). It is the result of a volume reduction in the ground beneath the surface, due to any of several possible mechanisms, as described below.

SDDR: Standard Dry Density Ratio:

Standard compaction method of determining Dry Density Ratio.

Subsidence:

Subsidence is often interchanged with settlement, in particular in relation to depressions left in roadways etc, following service trench construction. Subsidence may be assumed to be "*Downward movement, predominantly vertical in direction, due to removal, consolidation or displacement of the underlying strata".*

Superintendent:

The individual appointed by the contract principal as an independent arbiter of contract directions, issues, claims and variations.

Trafficable Area:

An area which is paved or is subject to vehicle loading. Areas are not considered trafficable where vehicle loading is rare and the area is not paved. Refer to section 3.1 for a detailed definition.

2 GENERAL REQUIREMENTS

2.1 Project Sequence and Responsibilities

With respect to the design and construction of backfill, the following process (summarised in Figure 1) shall be adopted:

A. The **Designer** shall consider pipeline alignment options and assess the cost and risk of each practical option in accordance with the MRWA versions of the WSA02 Sewerage Code of Australia or WSA03 Water Supply Code of Australia. This analysis shall consider the cost of installation and the risk of inadequate compaction and subsidence.

B. Where a trafficable alignment is optimum, the trafficable backfill requirements of this document shall be adopted by the **Contractor**.

C. Where a non-trafficable alignment is probably optimum and the backfill depth is less than 1.5m, the **Designer** shall specify that the performance requirements outlined in section 4 of this document shall be met by the Contractor.

D. Where backfill depth is greater than 1.5m and a non-trafficable alignment is probably optimum, the **Designer** shall determine if the local excavated material will have a significant amount of clay, clayey like soil or rock content. Refer to drawings MRWA-W-200 or MRWA-S-100 for guidance on how to identify these ground types.

E. If the answer to the question in item D is NO, the **Designer** shall specify that the performance requirements outlined in section 4 of this document shall be met by the Contractor. Such materials can be considered Low Risk.

F. If the answer to this question in item D is YES, the **Designer** shall engage and supervise a qualified Geotechnical Consultant (as per MRWA Construction Services Prequalification system when it is available) to assess the proposed non-trafficable alignment(s) and recommend backfill design(s).

G. The **Geotechnical Consultant** shall produce a backfill material and installation specification which will enable the performance requirements outlined in this document to be met at lowest community cost. This specification shall:

I. Consider and undertake cost and risk assessments on all reasonable material options which may include:

- Ordinary Fill (local or imported),
- Select Fill (local or imported),
- Granular material (100%), eg: Fine Crushed Rock or sand.
- Part Granular fill and part Ordinary / Select fill.

II. Nominate the backfill materials to be used and the level of processing (sieving etc) that is required.

III. Classify each proposed material as per Appendix D, Section 2 and Section C2 (in the commentary) of AS 2870-2011. Soils classified as A and S (Slightly Reactive) can be considered Low Risk. Soils classified as M (moderate), H1 (High) or H2 (Very High) can be considered High Risk. Installation requirements shall be suitable for the risk level. Soils classified as E (Extreme) can be considered Extreme risk and should probably not be used as backfill.

IV. Designate the installation requirements for each material and location. The maximum depth that any material can be used shall be specified (eg: 4m). If the Ordinary or Select fill proposed presents a high or extreme risk, a suitable granular material (eg: fine crushed rock or sand) should be specified below this level. Specify the installation parameters (using section 4.2.3 as a guide) for each backfill material.

V. Provide sufficient information to enable a Contractor to accurately estimate the

true cost of works and provide a specification which is detailed enough to be audited against.

H. Given the project specific backfill specification received from the Geotechnical Consultant, the **Designer** shall review the preliminary alignment analysis to verify that the proposed non-trafficable alignment(s) are still optimum.

I. During construction, the **Contractor** shall follow the project specific backfill specification and keep all records and evidence that the backfill specification is being fully complied with.

J. If at any stage the Contractor wishes to challenge a Geotechnical Consultant's backfill specification, the Contractor shall:

   i. Engage a different Geotechnical Consultant (at the Contractor's cost) to review the specification and the local situation on site,

   ii. Submit the Geotechnical Consultant's new recommendations to the Water Agency. (Note that the Water Agency is under no obligation to agree to the new recommendations),

   iii. If and when the Water Agency agrees to the changes and when appropriate, negotiate altered financial terms with the Superintendent.

K. The **Contractor** shall ensure that compaction testing as per this specification is undertaken and immediately notify the Superintendent and Water Agency of any non-compliant test results.

L. The **Construction Supervisor** for the project shall ensure that the backfill specification provided is being adhered to by the Contractor.

M. The **Contractor &/or Consultant** shall respond to any Test Failures and Subsidence as per section 6 of this specification.

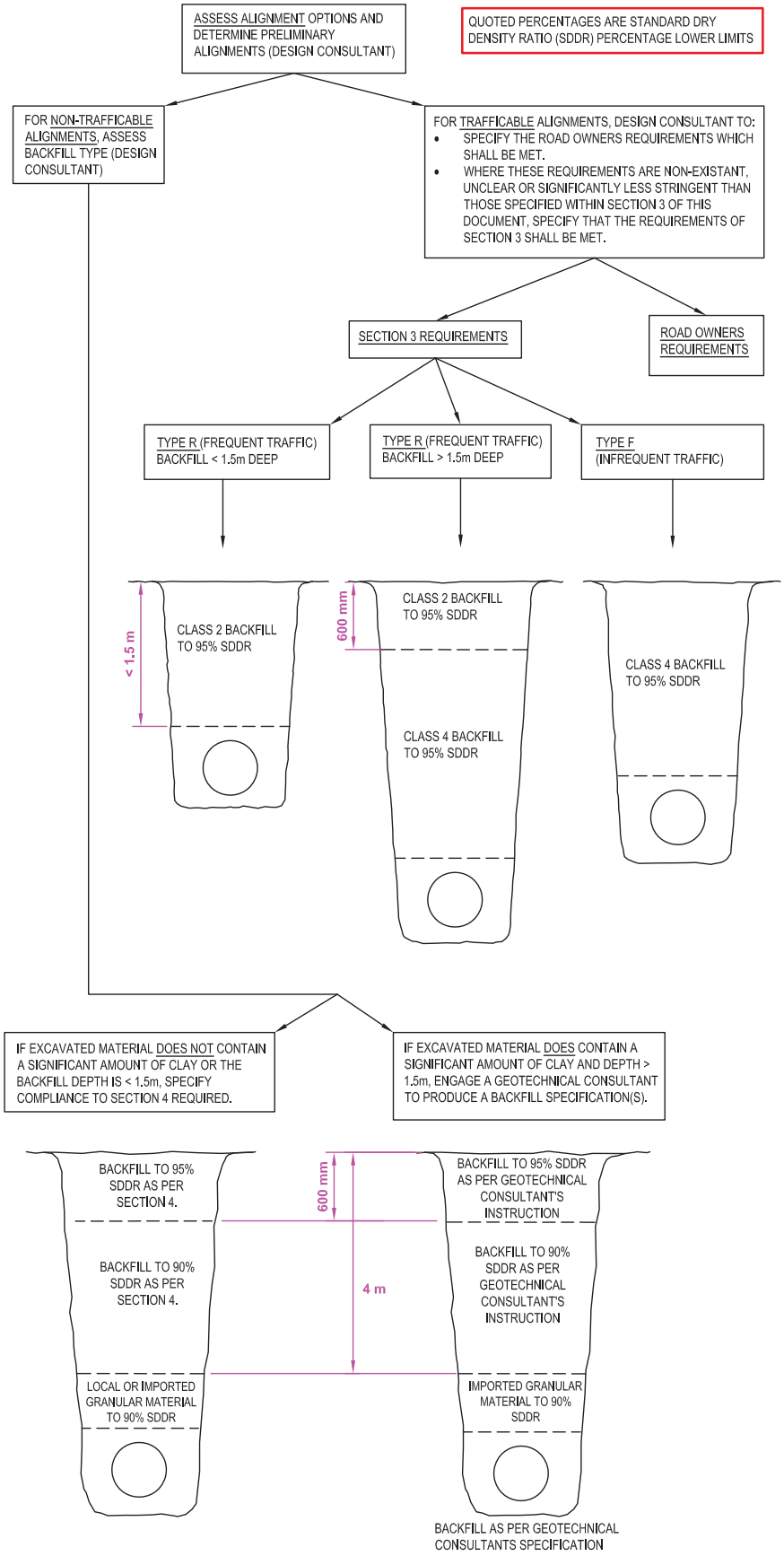


Figure 1: Backfill Design Process and Requirements Summary

In the assessment of backfill materials and suitable procedures, table 1 below can be used as a guide to help assess risks and controls.

Table 1: Backfill High Risk Factors

Risk Factor	Potential Responses
High plasticity heavy clay soils *(soils which can be formed / moulded into delicate shapes)*	Assess "reactivity" of the soil as per AS2870.2- 2011. Don't use the material (it may require extreme effort to compact). Compact in thin layers (ie: 100 to 200mm loose layers). Use forceful compaction equipment (eg: heavy roller or high impact equipment, hand held equipment may not be adequate)
High Rock Content or Large Rock fragments	Don't use the material. Sieve out a portion of the rock. Sieve out rock fragments > 75mm in size
Very low backfill moisture content	Don't leave spoil exposed to sunny / hot weather. Backfill soon after excavation. Add moisture.
Very high backfill moisture content	Remove excess moisture, allow the material to drain or dry off before placement.
Low strength surrounding soil (AHBP < 50 kPa) or close to other assets	Don't use forceful compaction equipment. Use easy to compact material in conjunction with low force compaction equipment &/or thin layers.
High ground water (esp when combined with high permeability soils)	Engage a Geotechnical Consultant to assess and recommend backfill options
Coode Island Silt	
Acid Sulphate Soils	
Variable or unknown backfill material	Check the material regularly and compare it against known material. Ensure that all backfill materials are carefully examined before use.

2.2 Mechanical Compaction

Mechanical compaction equipment shall be used to achieve the required density at the underside of each layer. Commonly used mechanical compaction devices are outlined in Table 2a and 2b below:

Table 2a: Compaction Equipment Summary

Mechanical Compaction Equipment	Type(s) Available	Comment
Tampers (whackers)	Walk behind	Useful in tight spaces and when working close to the top of pipe
Flat Plates	Walk behind or Excavator mounted	Can be placed with greater accuracy when working around structures
Rollers	Walk behind, Ride on or Excavator mounted	Obtain rapid compaction. Difficult to use in tight spaces

Table 2b: Compaction Equipment Variations and Options

Variations / Options	Comment
Pad foot / Sheeps foot	Effective with backfill high in clay. Concentrates the force on the smaller pads and acts to “knead” out air voids
Vibration	Vibration aids in reducing the sliding resistance of particles. Is more effective on granular materials.
Weight	Compaction takes less time / number of passes as applied downforce is increased. Excavators and Ride On plant are able to deliver much greater force than walk behind equipment. High force compaction equipment may not be able to be used close to underground structures.
Contact area	If the downforce is applied over a smaller area, pressure on the material is increased and compaction intensified

To protect the pipe from damage, the minimum thickness protective layers proposed in Table 4 must be placed over the pipe before the described compaction method can be used.

Table 4: Minimum Protective Cover

Compaction Method	Minimum protective cover over pipe
Hand held or walk behind compaction devices	300mm (compacted material)
Ride On plant compaction	500mm (compacted material)

The initial backfill layer on the embedment zone may need to be manually compacted (not machine assisted, eg: hand tamped) to ensure that the pipe is not damaged due to excessive force. Alternatively, a thicker protective backfill layer consisting of a granular material or a cement stabilised material may be used for the first backfill layer to protect the pipe from damage due to compaction forces.

2.3 Concrete Pipeline Support

Where a pipeline is supported on concrete, the Contractor must not place the embedment or backfill material until the concrete has obtained its initial set. Backfill must not be placed within 24 hours of placing the concrete, or longer where specified.

2.4 Impact of Other Works

Where other contractors (eg: road contractors) add fill over a pipeline trench as part of development activity and where they do not compact this material adequately, generalised subsidence may occur. Sewer and water construction contractors will not be held accountable for this subsidence, provided it is clear that the subsidence was not noticeably different at the pipeline trench.

3 TRAFFICABLE AREAS

3.1 Definition of Trafficable Areas

There are two different types of trench locations which shall be treated differently:

- Type R- Those locations that receive frequent traffic
- Type F- Those locations that receive occasional or rare traffic and those areas that require additional support to protect valuable assets (houses, pavement etc)

Type R locations include:

(a) The full width of any existing or proposed road carriageway plus shoulders and kerb,
(b) The full width of driveways and car parks,
(c) Any other areas that vehicles are likely to travel (eg: access tracks),

Type F locations include:

(a) In the side easement of private property within 3m of a building or building envelope,
(b) The ground next to the back of kerb equal in width to the main's cover to a maximum of 1m,
(c) The ground next to driveways and car parks equal in width to the main's cover to a maximum of 1m,
(d) The full length of any constructed footpath (including, but not limited to concrete, asphalt, crushed rock footpaths).
(e) The ground next to footpaths equal in width to the main's cover to a maximum of 1m,
(f) The full width of any median strip,
(g) Within 1.5m of a sewer maintenance structure, shaft or riser (jump up) which is located in a non trafficable area,
(h) Within 400mm of a pressure main surface fitting (hydrant riser and cover, valve spindle and cover) which is located in a non trafficable area,
(i) Any other areas where controlled compaction is required to minimise the potential of subsidence.

Where part of the trench's width is located within the above mentioned zone(s), the full width of the trench then needs to be backfilled to the higher specification. Typically, only assets which have less 1.5m cover can be located in the nature strip while still using Non Trafficable backfill. It is usually not possible to wholly contain deeper trenches within the narrow Non Trafficable part of the nature strip.

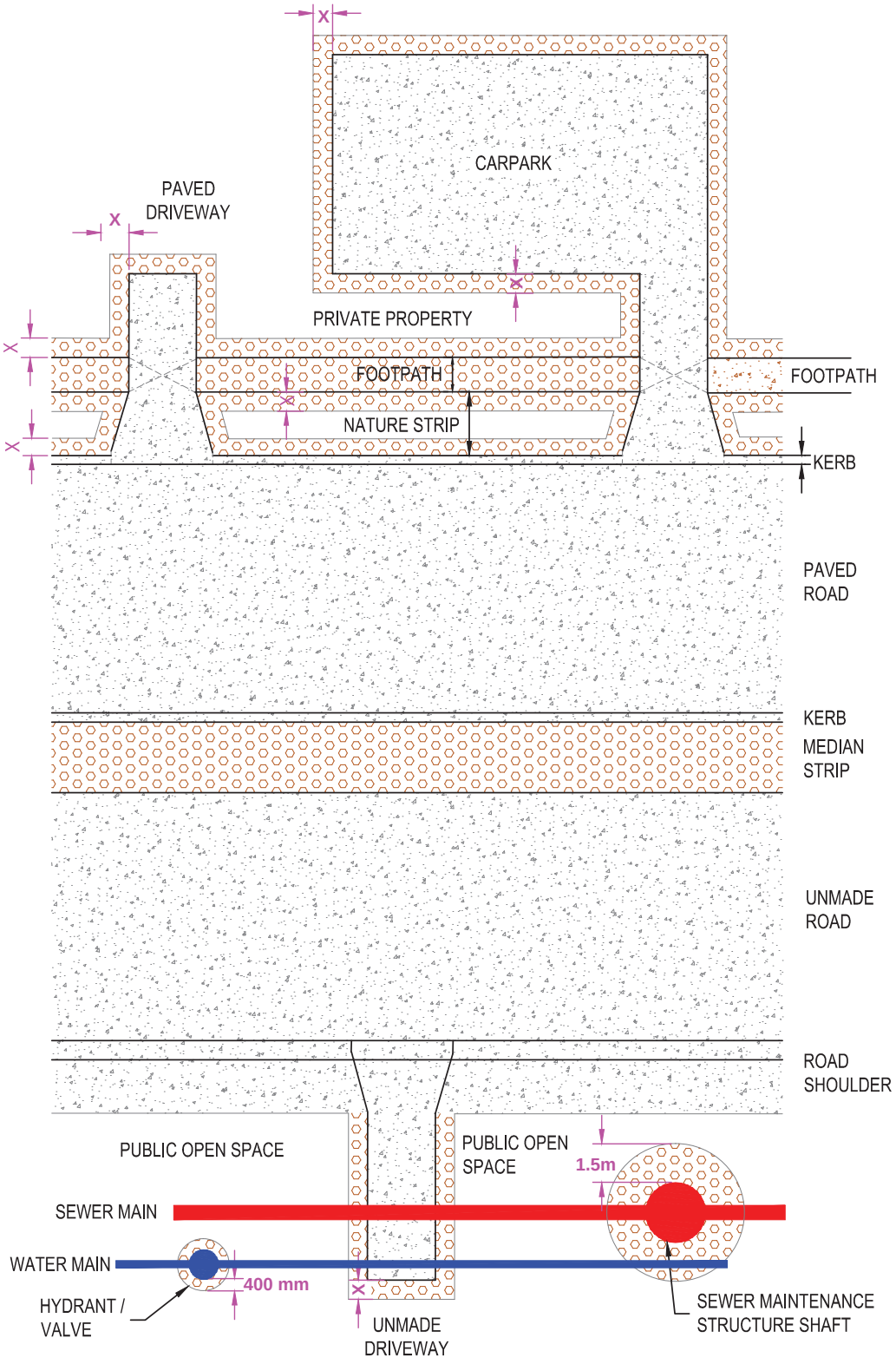


Figure 2- Trafficable Backfill Types and Locations

3.2 Road Owners Requirements

The Road Authority's requirements are defined to be the requirements described in the Road Authority's standard specifications and drawings with respect to trafficable areas as defined in Clause 3.1.

The backfill arrangements for trafficable areas shall be acceptable to the Road Authority, and in accordance with its' standard specification and drawings.

If the Road Authority's requirements for trafficable areas exceed or are approximately equivalent to the requirements of section 3.3 of this specification, then the Road Authority's requirements shall take precedence.

If the Road Authority's requirements are non-existent, unclear or significantly less stringent than those specified in section 3.3 of this specification, then section 3.3 of this specification shall be adopted.

3.3 Requirements where Road Owner Requirements do not Take Precedence

3.3.1 *Backfill Material*

All trafficable backfill material shall be as per table 5:

Table 4: Trafficable backfill material standards.

Material	Specification
20mm Class 2 or 4 Fine Crushed Rock (FCR)	Vic Roads Standard 812
20mm Class 4 Crushed Scoria (not acceptable for CWW water supply projects)	Vic Roads Standard 818
20mm Class 4 Crushed Concrete	Vic Roads Standard 820

A dispensation is required from the water Agency to use native cohesionless soils as trafficable backfill.

Backfill material shall comply with the following:

Type R locations:

- For trenches less than 1.5 metres deep, the backfill shall be 20 mm Class 2 Plant Mixed Wet Mix backfill for the full depth.
- For trenches 1.5 metres deep or greater, the backfill shall be:
  - **i.** 20 mm Class 2 Plant Mixed Wet Mix backfill for the top 600 mm.
  - **ii.** 20 mm Class 4 (or better) Water Agency approved backfill for the remainder.

Type F locations:

Water Agency approved 20 mm Class 4 (or better).

3.3.2 *Backfill Density*

Using the Modified Compaction test (AS1289.5.2.1) the minimum dry density ratio (AS1289.5.4.1) required shall be as per table 6:

Table 5: Minimum trafficable density requirements.

Layer	Minimum Density
Top Pavement (eg: concrete & asphalt, to min depth of 100mm)	98% SDDR
Crushed Rock Layer between 100mm and 300mm deep (sub-base)- if relevant	95% SDDR
Below 300mm; If Crushed Rock: If sand (Special dispensation from the road owner and/or Water Agency would be required):	 95% SDDR 80% (minimum density index) or 10 blows/300mm (PSP)

These densities are required for trench fill under all trafficable areas including footpaths.

3.3.3 *Backfill Placement & Compaction Procedure*

Moisture condition the backfill material (in accordance with section 4.2.4), place in layers of uniform thickness and mechanically compact using a proven method (ie: a method which has been proven through laboratory testing to produce adequate compaction).

4 NON TRAFFICABLE AREAS

4.1 Definition of Non Trafficable Areas

Non trafficable areas are those other than that defined in section 3.1 of this specification.

4.2 Cohesive Soils

4.2.1 *General Information*

This clause applies to the use of soils which are either clay or are sufficiently clayey in composition that they will behave in a clay-like manner when placed and compacted as trench backfill.

Geotechnical advice should be sought in relation to moisture conditioning, for which the requirements of Clause 4.2.5 may not be applicable.

Do not use granular material for backfill in areas where the natural soils are reactive clays (e.g. high expansion / contraction basaltic clays) and there is a structure nearby which may be sensitive to differential movement.

4.2.2 *Backfill Material*

Geotechnical consultants are required to provide customised designs for clay or clay like cohesive soils. Ordinary or Select Fill shall be limited to a depth of 4m or not used (if the risk is deemed to be unacceptable). Backfill at depths deeper than this shall utilise a granular material.

Some Ordinary Fill may behave essentially as a cohesive material, but may contain greater than 20% of rock material which is coarser than 37.5 mm. Such material may be acceptable as backfill, but cannot be tested using the methods of AS1289. As compaction testing is not possible, special dispensation will be required from the Water Agency to use this material and more rigorous risk controls (eg: higher level of auditing) will need to be adopted.

4.2.3 *Cohesive Soil Backfill Specification Template*

The following template shall be completed by the Geotechnical Consultant for each section of pipeline where a significantly different clay or clay like cohesive soil is to be utilised:

Table 6: Backfill Specification Template (blue text is example text only).

Line Description	
Section End Description (M structure, X-Y, Address)	POG 36-1
Section End Description (M structure, X-Y, Address)	90m towards POG 36-2 from POG 36-1
Linear Distance	90m
Number of Compaction Tests Required	1

Specification	***Upper Depth Range***	***Lower Depth Range (if required)***
Depth Range	4.0 m to surface	Main depth to 4.0 m
Optimum Backfill Material Description	Local mixed clay and rock excavated material	Class 4
Backfill Material Requirements	< 20% rock fraction < 75mm rock size	Vicroads 812
Soil classification as per Appendix D, Section 2 and Section C2 of AS 2870-2011	H1 (high)	N/A
High Risk Factors Likely to be Found (refer Table 1)	High ground water, high reactivity clay soil, large rocks	High ground water, predominantly rock

Risk Controls Required	*Geotechnical Consultant to potentially nominate risk controls such as: moisture conditioning, prescribed construction sequence, compaction trials, non standard trench support, dewatering requirements, geotechnical inspections or supervision.*	
Compaction Machine	Excavator	Excavator
Compaction Type	Pad foot roller	Vibrating Plate
Compaction Weight (of excavator)	> 30 ton	> 15 ton
Number of Passes per Layer	> 6	N/A
Loose Layer Thickness	< 200mm	< 200mm
Moisture Limits	> 90% & < 110% of optimum	> 85% & < 115% of optimum
Max time to stockpile (dry & temp b/w 20 & 30 dec C)	48 hours	48 hours
Max time to stockpile (dry & temp > 30 dec C)	24 hours	24 hours
Material Test Data Results	*Geotechnical Consultant to reference any relevant data or analysis and insert these documents as an appendix to the design, eg: bore log data or Plasticity Index results*	
Risk and Cost Assessments	*Geotechnical Consultant to include backfill risk and cost estimates as an appendix to the design*	

4.2.4 *Backfill Density*

Non trafficable cohesive soil backfill shall be placed to achieve the minimum compaction levels described in Table 7.

Table 7: Non Trafficable Density Ratio Requirements (modified)

Within Trenchfill Zone and :	Minimum SDDR
In the 600mm layer below the finished surface level	95% (minimum)
Deeper than 600mm below the finished surface level	90% (minimum)

Clean top soil placed uniformly above a wide area of compacted material does not require compaction.

4.2.5 *Moisture Conditioning*

The moisture content of the fill is critical to achieving the specified minimum compaction requirements. The fill shall be moisture conditioned as necessary to achieve the required relative compaction.

Moisture conditioning of fill shall be carried out as required, providing the Contractor:

- Has an approved inspection and test plan in place, which is used to control the process.
- Pays for the water taken from the Water Agency's reticulation system.
- Use Class A or B non drinking water if practicable, or potable water should recycled water not be practicable.
- Uses an approved Backflow Prevention Device.
- Takes steps to ensure that water is not wasted.
- Takes preventive measures to contain water containing sediment, and in particular, prevent it entering drains and water courses.

4.2.4.1 Moisture Content Standard

Moisture content shall be between 85% and 115% of the Standard Optimum Moisture Content, as determined by AS 1289.5.1.1 or AS 1289.5.7.1.

4.2.4.2 Field Test for Optimum Moisture Content (OMC)

The following empirical test is provided for the information of the Contractor only. It is NOT a method statement or advice, nor is it a direction from the Principal or Superintendent or their representatives, nor is it designed to replace expert advice. This information in no way reduces the Contractor's responsibility to ensure that the backfill moisture content is correct in order to achieve the specified densities.

As a field guide to assessing whether a clayey soil is near its Optimum Moisture Content (OMC) for Standard Compaction (AS 1289 5.1.1), the following test is useful.

A representative handful of material proposed for use as backfill is squeezed in the hand. Suitable material should be wet enough so that it binds together with no more than slight crumbling when the hand is opened, and not so wet that it is at all plastic or slippery, nor exudes water when the material is well shaken in the hand. Clayey material, at about standard OMC should be able to be rolled into a worm, approximately 2 mm in diameter, but when an attempt is made to bend the worm, it should not bend but should break.

When compacted against a firm surface, the material of correct moisture content should not surge ahead of the roller or other equipment and should not rebound excessively after wheel loading. It should readily bind together under the rolling action.

5.3.1.1. Dry Fill (<OMC)

Possible action to increase the moisture content of stockpiled backfill material could include finely spraying water and uniformly blending water through the dry fill and mixing it to provide a consistent moisture distribution. Allow time (overnight) for clayey soils to cure.

It is recommended that minimising the time between excavation and re-compaction of the excavated material is the best method of achieving the OMC and the compaction target. It is very difficult to properly moisture condition the excavated material once it has dried out. The Contractor must therefore consider the need to limit the amount of trench excavated at any time to the amount that it

can manage with the level of equipment and resources on site. This is of particular importance during summer when elevated temperatures and low humidity can rapidly reduce moisture in excavated material.

Material excavated during periods of drought or at the end of a long dry summer may have insufficient moisture content and may affectively be unworkable without the addition of moisture.

5.3.1.2. Wet Fill (>OMC)

Possible action to decrease the moisture content of stockpiled backfill material could include blending the fill with drier material using a plug mil or similar, or aerating the fill. If the fill is excessively wet it may be difficult, if not impossible to achieve the specified compaction, and specialized advice shall be sought.

4.2.6 *Flooding and Jetting- Not Permitted:*

Flooding or jetting of cohesive fill materials in excavations is **not permitted under any circumstances**. Cohesive soil fill that has been flooded or jetted shall be rejected, and the Contractor shall replace the fill material, in accordance with this Specification, at its own cost.

4.2.7 *Backfill Placement and Compaction Procedure*

Moisture condition the backfill material (in accordance with section 4.2.4) if required, place in layers of uniform thickness and mechanically compact to achieve the designated performance criteria. Comply with any requirements specified by the Geotechnical Consultant.

4.3 Cohessionless Soils

4.3.1 *General Information*

Cohessionless soils will typically be clean sands or silty sands.

Unless specifically approved by the superintendent, cohesionless soil fill is only to be used in those areas where the natural soils within which works are being undertaken are also cohesionless. Where cohesionless soil fill is proposed in areas where the natural soils are clayey, and consequently may be reactive, special considerations may need to be applied. In such circumstances, the designer may impose additional requirements to those given in this Specification.

Backfill shall be compacted to achieve the minimum relative compaction described below, in terms of Density Index (AS 1289.5.6.1) or penetration resistance using a Perth Sand Penetrometer (PSP) (AS 1289.6.3.3).

Note: With sands compacted using mechanical means, the surface soils may be loosened by the process. Testing of the penultimate layer is often required to assess compliance. The final layers will then require additional attention to achieve compliance, often with static rolling compaction.

4.3.2 Compaction Density

Minimum Density Index of 60%, or

Minimum PSP / DCP Penetration resistance of 7 blows per 300 mm.

4.3.3 Flooding

Flooding of backfill as means of attempting compaction is not permitted.

4.3.4 *Mechanical Compaction and Compaction Procedure*

Place in layers of uniform thickness and mechanically compact to achieve the designated performance criteria. Backfill below a depth of 4m shall be granular.

5 DRIVES, SHAFTS, TUNNELS AND BORES

Impact loading of the structures and appurtenances must be avoided during the placement of backfill.

5.1 Shafts and Vertical Structures:

Where fill is placed around shafts or other vertical structures, the fill shall be placed and compacted evenly around the shaft or structure to prevent displacement. Care shall be taken to place and compact the fill evenly around the structure in thin layers, to avoid unbalanced lateral loading.

High compactive effort shall not be used against structures to ensure damage to the structure is prevented. Particular care must be taken adjacent to house sewer connection branches and retaining walls.

All open trench within 1.5m of the perimeter of a shaft, vertical structure or rising pipe shall be backfilled as per Trafficable Backfill (section 3). Trafficable backfill may be used in lieu of non-trafficable fill at any time. Whether this is Type R or Type F shall depend on the location of the shaft as defined in section 3.1. Where a shaft or structure crosses between different area types (Type R trafficable, Type F trafficable or non trafficable), the higher class of material shall be used around the entire structure.

5.2 Shafts and Vertical Structures in Non Trafficable Areas

Maintenance Structures and other vertical structures in non trafficable areas shall be backfilled in accordance with Figure 3 below. The steps in Fig 3 Section C indicate the sequence at which backfill shall occur. Each step involves placement and then compaction before the next step occurs. Each class 4 backfill placement should provide sufficient loose fill material so that once compacted it is approximately level with the adjacent compacted ordinary fill. Class 4 may be used in lieu of Ordinary fill at any time.

Where trenches are located in tight built up areas where there is limited vehicle access, the requirement for Type F backfill may be discussed with the Water Agency. In such cases, alternate risk controls may be more suitable than the requirement for Type F backfill. Such cases would need to be considered on a case by case basis.

5.3 Type 2 House Connection Branch Jump Ups in Non Trafficable Areas

Type 2 property connection jump ups in non trafficable areas shall be backfilled in accordance with Figure 4 below. The steps in Fig 4 Section F indicate the sequence at which backfill shall occur. Each step involves placement and then compaction before the next step occurs. Each class 4 backfill placement should provide sufficient loose fill material so that once compacted it is approximately level with the compacted ordinary fill.

Once the class 4 backfill has been compacted to above the top of the jump up, subsequent layers above the jump up may consist of ordinary fill.

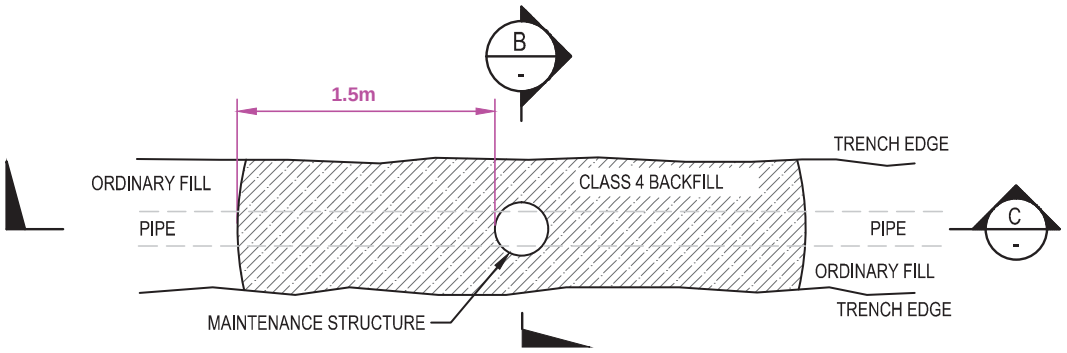
5.4 Type 4 House Connection Branch Jump Ups in Non Trafficable Areas

Type 4 property connection jump ups in non trafficable areas shall be backfilled in accordance with Figure 5 below. The steps in Fig 5 Section I indicate the sequence at which backfill shall occur. Each step involves placement and then compaction before the next step occurs. Each class 4 backfill placement should provide sufficient loose fill material so that once compacted it is approximately level with the compacted ordinary fill.

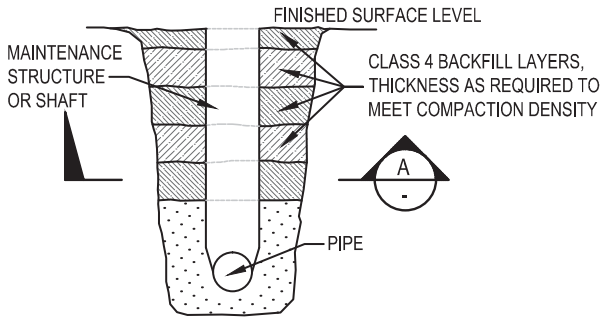
5.5 Drives and Tunnels

Drives and tunnels must be refilled above the embedment zone using the following materials and methods:

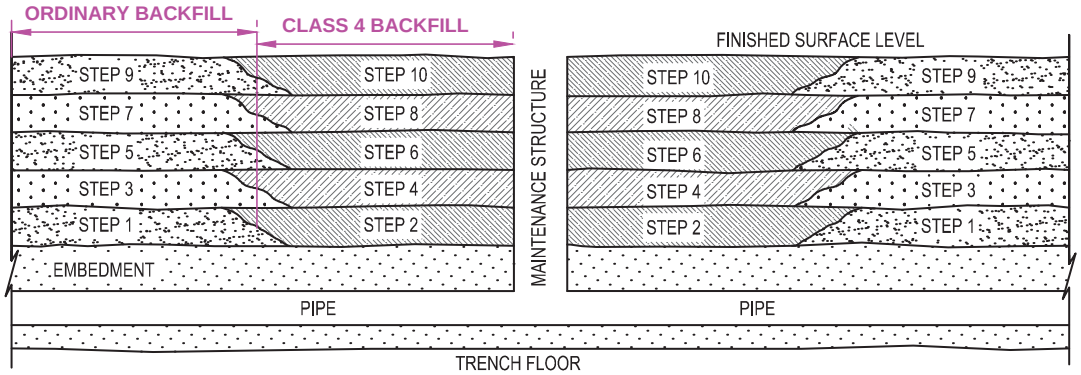
- 20 mm Class 4 crushed rock, or embedment concrete sand or 5 mm minus (blown in, not compacted),
- Grouting, either by gravity, or under pressure. (Gravity grouting shall only be used for tunnels where there is sufficient head.)



PLAN VIEW A - MAINTENANCE SHAFT TRENCH BACKFILL



ELEVATION B - MAINTENANCE SHAFT TRENCH BACKFILL



SECTION C - MAINTENANCE SHAFT TRENCH BACKFILL

NOTE: DRAWINGS ARE SCHEMATIC, ARE NOT TO SCALE AND DO NOT SHOW PIPEWORK DETAILS. FOR THIS INFORMATION, REFER TO THE MRWA VERSION OF THE SEWERAGE CODE OF AUSTRALIA.

Figure 3: Backfill Around Shafts and Vertical Structures in Non-Trafficable Areas

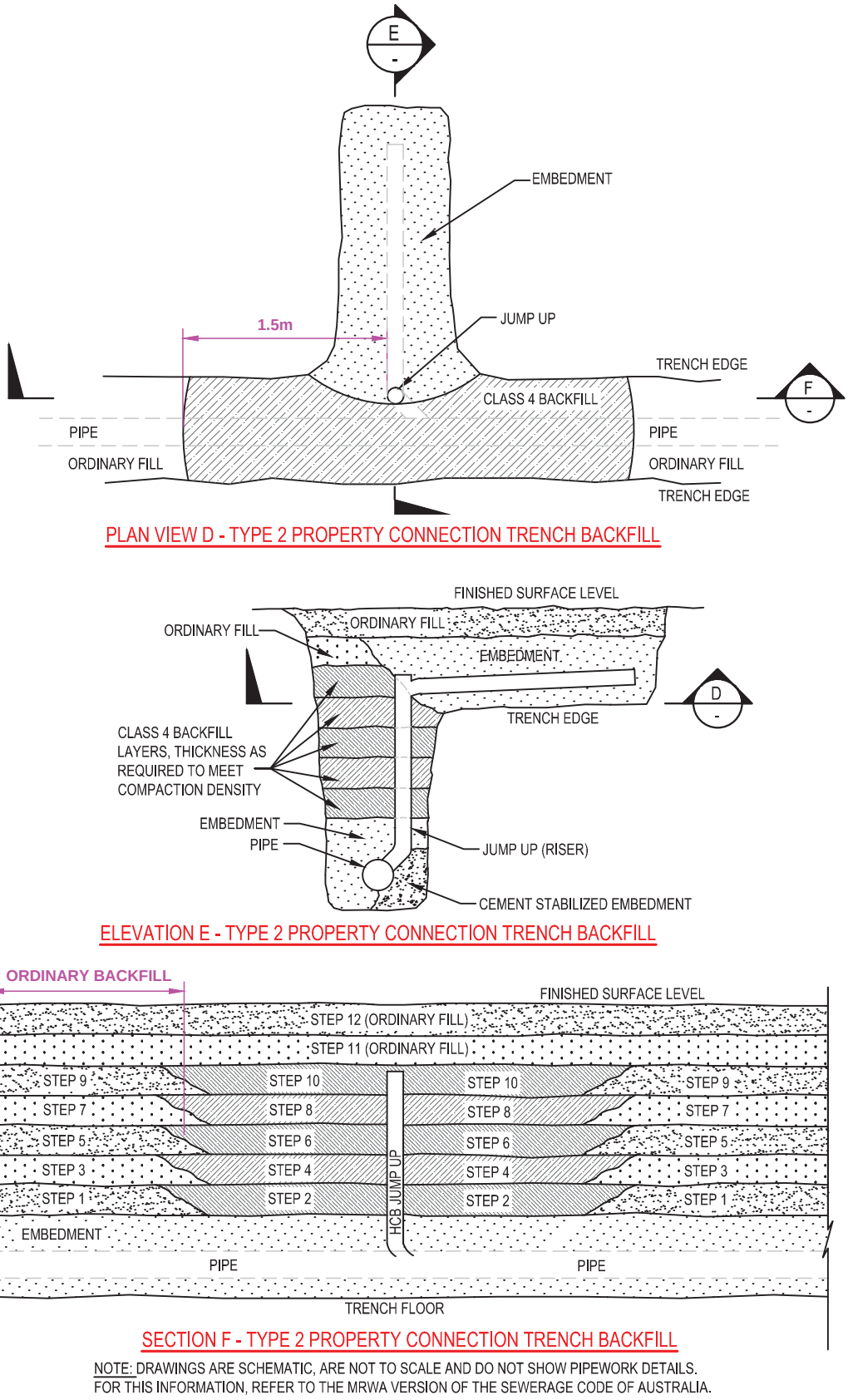
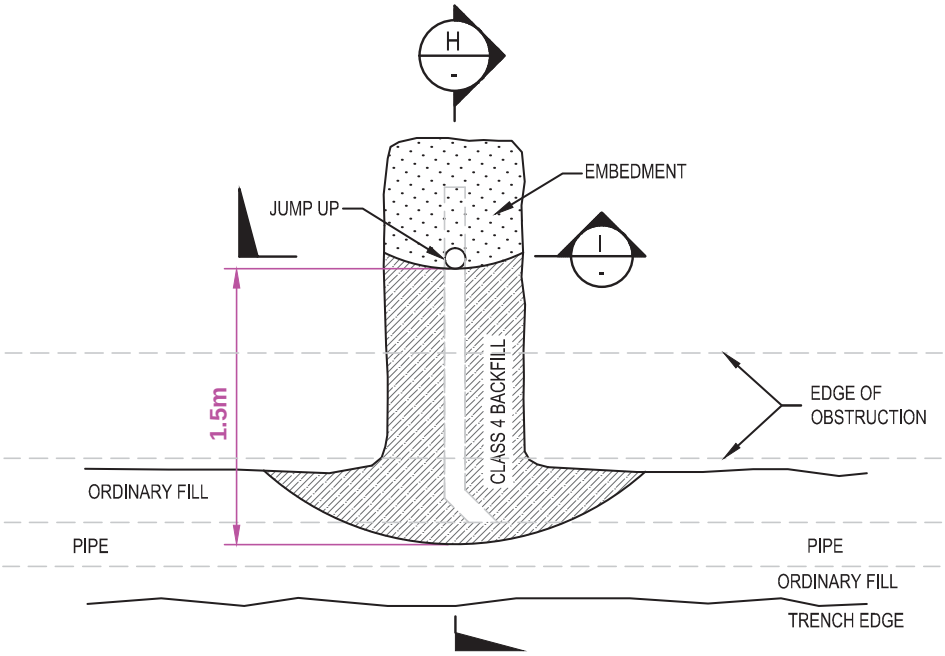
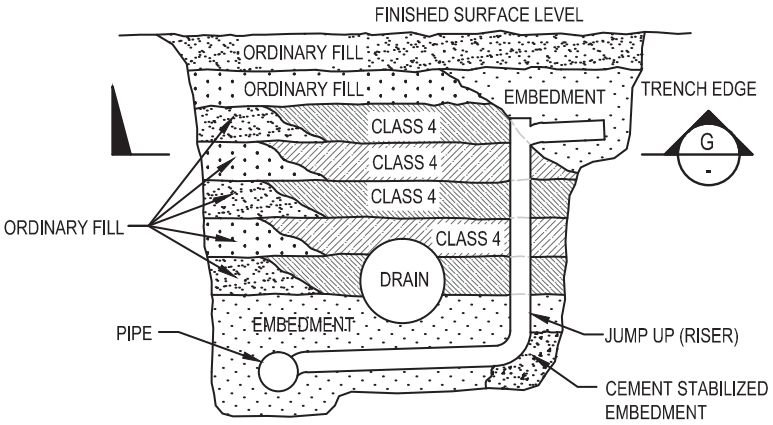


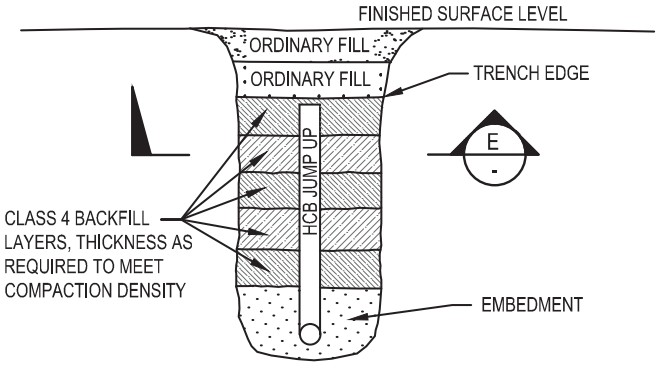
Figure 4: Backfill Type 2 Property Service Jump Ups in Non-Trafficable Areas



PLAN VIEW G- TYPE 4 PROPERTY CONNECTION TRENCH BACKFILL



ELEVATION H - TYPE 4 PROPERTY CONNECTION TRENCH BACKFILL



SECTION I- TYPE 4 PROPERTY CONNECTION TRENCH BACKFILL

NOTE: DRAWINGS ARE SCHEMATIC, ARE NOT TO SCALE AND DO NOT SHOW PIPEWORK DETAILS. FOR THIS INFORMATION, REFER TO THE MRWA VERSION OF THE SEWERAGE CODE OF AUSTRALIA.

Figure 5: Backfill Type 4 Property Service Jump Ups in Non-Trafficable Areas

5.6 Grouting

Grout for backfilling or void filling shall be one of the following:

1) a commercially manufactured cementitious grout from manufacturers such as Hanson (Liquifill) or Parchem (Conplast / Alofix).
2) a high strength polymer foam (10% strain compressive strength of > 200 kPa) such as Benefil (Urea Formaldehyde).

Grouting of tunnels, drives and bores must be carried out within 24 hours of pipe placement by one of the following methods. Grouting of bores is not required where the diameter of the bore exceeds the outside diameter of the pipe by less than 40 mm.

Measures shall be undertaken (ie: pipe centralisers) to ensure that the pipe does not move due to flotation during grouting.

5.6.1 *Gravity Grouting:*

The grout can be allowed to flow under gravity to fill the excavation. The grout must be placed in shafts and allowed to flow into the drives to completely fill them. Excess water must be removed progressively. Care must be taken to prevent the drives becoming air-bound and, if necessary, the Contractor shall provide riser holes for the release of entrapped air. Grout from the downstream end to aid in expelling air from within the void.

Where practicable, riser holes shall be drilled and cleaned out prior to placement of the grout, and shall be maintained in a clear condition during the grouting operation. Riser holes shall be between 75 mm and 300 mm in diameter.

If backfilling against a bulkhead, the Contractor shall provide, at the top of the bulkhead, a horizontal proving hole not less than 50 mm diameter. The Contractor shall maintain the proving hole in a clear condition.

A substantial surcharge must be maintained above the roof of the tunnel, drive or bore throughout the placing operation. Placing shall continue without interruption until, by the presence of slurry in the risers and by the cessation of movement in the free surface, it is apparent that the tunnel, drive or bore is full, or until directed by the Superintendent that the filling be discontinued. Grout must not be permitted to rise above 600 mm below ground surface level.

5.6.2 *Pressure Grouting:*

The grout is forced into the excavation using air or mechanical pressure. Riser holes and proving holes shall be constructed where practicable and maintained if necessary, and the grout placed to a level in the riser holes as specified for gravity grouting. The grouting pressure shall be controlled to ensure the pipe is not crushed.

5.7 Voids Behind Timber Ground Support

In close-timbered tunnels, drives and shafts, the Contractor shall fill the voids behind the timber ground support by pressure grouting or other approved means.

6 COMPACTION TESTING

Compaction testing shall be undertaken as per the road owners requirements for trafficable areas. In non trafficable areas or where no requirements are specified by the road owner, the following requirements shall be met.

Quantitative compaction testing by an appropriately NATA accreditation company is required to provide soil density results to periodically verify that the adopted procedure is continuing to be successful.

Tests in excess of the amounts described below may be requested by the Water Agency should the Agency be concerned that subsidence risks are not being adequately addressed.

These tests shall be done at the cost of the Water Agency unless a test result fails, in which case the Contractor shall pay all costs for the testing and rectification works.

Compaction test samples (for laboratory testing) shall be taken from either side of the compaction layer.

6.1 Provision of Safe Environment for Field Density Testing

The contractor shall provide a safe worksite for the specified testing to occur. This shall include:

a. Preparation, in consultation with laboratory staff, of an approved safe working procedure that complies with the requirements of all OHS legislation, regulations and codes of practice.
b. Provision of equipment (for example trench shields) to make excavations safe at the locations selected for testing.

6.2 Quantitative Testing Amounts

Test sites shall be established as directed by the Geotechnical Consultant or as per table 8, whichever is greater.

Table 8: Compaction Test Site Quantities

Situation		Pipeline test sites	Gravity Sewer Maintenance structures	Pressure Pipeline Surface Fittings & HCB Jump Ups
A	Cohesive Soils (non trafficable)	1 per 100m length of pipe (0.01 / m)	Cohesive and Cohesionless backfill is not permitted within 1.5m of a maintenance structure. As per Type R or F locations only.	Cohesive and Cohesionless backfill is not permitted within 0.4m of a pressure surface fitting or within 1.5m of HCB Jump Ups. As per Type R or F locations only.
B	Cohesionless Soils or granular material (non trafficable)	1 per 200m length of pipe (0.005 / m)		
C	Backfill in Type R trafficable locations	1 per 50m length of pipe (0.02 / m)	2 in 5 structures (40%)	1 in 10 (10%)
D	Backfill in Type F trafficable locations	1 per 100m length of pipe (0.01 / m)	1 in 5 structures (20%)	1 in 20 (5%)

For the purposes of determining testing amounts, calculations may be rounded up or down as per the normal convention.

Where the project quantities are less than half of those nominated in table 8 such that the test quality rounds down to zero, the contractor shall accumulate quantities from a number of projects (separately for each Water Agency) over time until the contractor reaches half the quantity nominated in table 8. Testing shall then be undertaken.

6.3 Examples- Test Site Quantities

Example 1:

- 160m of pipeline constructed in type F trafficable location (situation D)
- 3 maintenance structures constructed

Testing Required: 2 pipeline locations (0.01 x 160 = 1.6 then rounded up)
1 maintenance structure location (0.2 x 3 = 0.6 then rounded up)

Example 2:

2 projects, each consisting of:

- 40m of pipeline constructed with cohesive soil backfill (situation A).
- 2 maintenance structures constructed (in nature strip- Type F)

Testing Required: 1 pipeline locations (0.01 x (40 +40) = 0.8 then rounded up)
1 maintenance structure location (0.2 x (2+2) = 0.8 then rounded up)

6.4 Reduction in Test Site Quantities

Laboratory testing requirements may be reduced should the Water Agency auditor or an authorised person provide written permission. Such permission may be granted if:

- the risk of inadequate compaction is low
- the trench is not particularly deep
- the compaction procedure has been randomly witnessed (by the Water Agency auditor) as having been completed as documented
- the construction crew and company historically have good backfill performance
- checks (eg: DCP measurements) undertaken by the Water Agency auditor indicate that compaction densities have been achieved

6.5 Test Site Selection (for backfill verification)

Unless a Water Agency delegate is unavailable, the Water Agency shall mark the position (with spray paint after backfill has been completed) that a test site shall be constructed and the test site shall be immediately set up without any further compaction taking place, preferably with the Water Agency auditor still present.

To facilitate this site selection, the Contractor shall provide written notification (with the required time in advance) to the Water Agency via the standard notification of the Intent to Carry Out Testing process.

6.6 Test Site Set Up and Test Locations

Undertake testing as per Figure 6 and Figure 7. Probes shall not be inserted to within 0.5m of top of pipe. Laboratory samples shall be taken and analysed at all locations where Nuclear Densometer testing is undertaken.

Dynamic Cone Penetrometer (DCP) / Perth Sand Penetrometer (PSP) testing shall be undertaken through the range of depths being tested using Nuclear Densometer testing to provide an immediate indication of compaction density. DCP test results can be later calibrated to the more accurate laboratory and Nuclear Densometer test results. This calibration will also assist in correlating deeper DCP test results with compaction density.

Test pits shall be excavated to a maximum depth of 1.5m (to enable safe entry without shields) or to a depth equal to the pipe obvert plus 0.8m, whichever is shallower. They shall be benched at 0.5m depth increments to enable Nuclear Densometer testing to be undertaken at these locations.

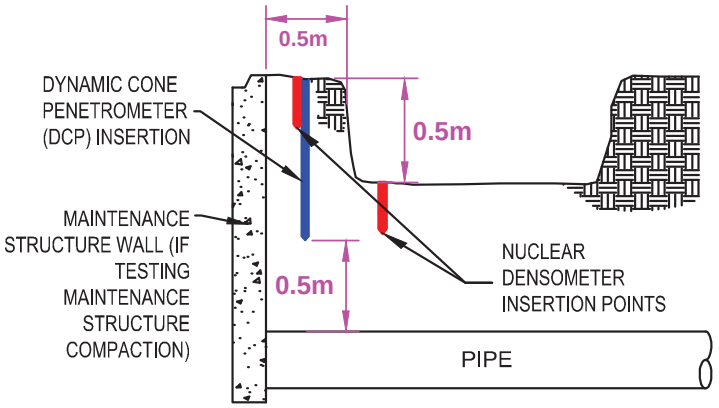


Figure 6: Compaction testing for Shallower Pipe installations

For the test site shown in Figure 6, two Nuclear Densometer and one DCP tests would be required. For shallower pipe, DCP testing from the test pit floor may not be required.

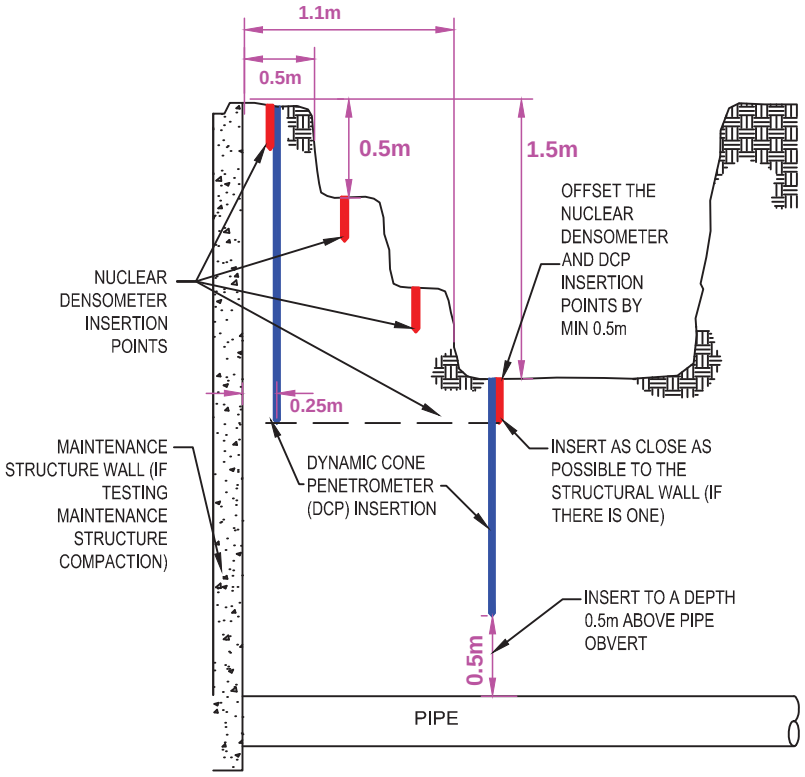


Figure 7: Compaction testing for Deeper Pipe installations

For the test site shown in Figure 7, four Nuclear Densometer and two DCP tests would be required.

Typically Dynamic Cone Penetrometer (DCP) testing may be difficult to perform over depths greater than 2m. Where the main is deeper than 4.0m, safe testing of the backfill is therefore difficult to perform. For this reason, at depths greater than 4m, only lower risk granular backfill material shall be used.

Should the DCP cone refuse to penetrate further, use a hand auger to open out the hole and remove the obstruction or retest in a different position.

Trench compaction is typically more difficult to achieve close to the sides of the trench. Tests shall be undertaken as close to the **side of the original trench** as possible while still being certain that newly compacted ground is being tested.

6.7 Compaction Testing – Method

The field dry density (Nuclear Densometer) and laboratory compaction tests shall be carried out on a one to one basis. (i.e. one laboratory compaction test shall be carried out for each field dry density test).

Testing shall be undertaken in accordance with the following:

- AS 1289.2.1.1 Soil moisture content test.
- AS 1289 5.1.1 Soil compaction & density test- Determination of the dry density / moisture content relation of a soil using standard compactive effort.
- AS 1289 5.1.2 Soil compaction & density test- Determination of the dry density / moisture content relation of a soil using modified compactive effort.
- AS 1289 5.4.1 Soil compaction & density test- compaction control test- dry density ratio, moisture variation and moisture ratio.
- AS 1289 5.7.1 Soil compaction & density test- compaction control test- Hilf density ratio and Hilf moisture variation (rapid method).
- AS 1289 5.8.1 Soil compaction & density test- determination of field density and field moisture content of a soil using a nuclear surface moisture-density gauge- Direct transition mode*.
- AS 1289 6.3.2 Soil strength and consolidation tests- Determination of the penetration resistance of a sol- 9kg dynamic cone penetrometer test.

*The Nuclear Density Gauge method of field dry density measurement shall only be used in a trench where it can be demonstrated that the effects of reflected radiation from the walls of the trench are adequately compensated for.

Where the backfill contains greater than 20% rock (volume) which is coarser than 38mm in diameter, compaction testing as per AS 1289 will not be able to be undertaken. In such cases, the Water Agency shall be notified of this in writing so that stricter than usual risk controls and surveillance programs can be put in place. The need for testing may then be waived by the Water Agency.

7 RESPONSE TO TEST FAILURE AND SUBSIDENCE

7.1 Laboratory Test Result Failure

The compaction testing laboratory and Contractor shall report any test result failures (with a copy of the full report) to the Superintendent, Water Agency and Contractor (to the relevant contact listed in Table 9) within 1 business day of the result being determined.

The Water Agency will then determine the appropriate next step. If the Water Agency requires that corrective action(s) be undertaken, they will raise a formal NSIR (CWW), observation (YVW) or issue (SEW) and send it to the Contractor.

Typically, the Water Agency will require that additional test sites be constructed and subsequently tested on both sides of the failed test site (2 additional sites). These test sites shall be approximately midway between the original test sites.

All additional testing undertaken as a consequence of a non conforming test result shall be undertaken at the cost of the contractor.

Table 9: Water Agency contact emails

Water Agency	Contact Email
City West Water	standards@citywestwater.com.au
South East Water	standardsissues@sewl.com.au
Yarra Valley Water	standards@yvw.com.au

7.2 Subsidence

As trench subsidence may occur months or years after inadequate backfill work has been undertaken, the Contractor may be held responsible and held accountable for subsidence after an extended period of time.

Subsidence reports which come in from the public or from an auditor will be initially investigated by the Water Agency. Through an examination of the available evidence, the cause of the subsidence will then be established.

If the Contractor believes that the Geotechnical Consultant's Backfill procedure is at fault, this procedure can be independently assessed by a third party Geotechnical Consultant to ascertain if it was appropriate. Where there are significant concerns about the validity of the procedure, the Contractor will not be found at fault.

One common cause for subsidence is poor backfill work carried out by another party (eg: drainage, road or plumbing contractor). Where it is clear that subsidence has occurred directly above the constructed sewer or water trench and at locations not at a connection point, fault will likely be found with the sewer or water Contractor.

Should the Water Agency believe that the subsidence was caused by inappropriate backfilling on the part of the Contractor, a non conformance will be raised so that the contractor can attend to the fault. This may occur whether the asset is under warranty or not.

Where the Water Agency has had to undertake emergency works to control a safety hazard associated with subsidence, all costs incurred as a result of this emergency work shall be reimbursed to the Water Agency by the Contractor.

7.3 Failure Response Process

Should the Water Agency raise a non conformance, issue or observation due to a test result failure or subsidence, the Contractor shall then follow that Water Agency's non conformance / issue / observation process which typically consists of the following steps:

- The Contractor investigates the incident, gathers evidence, interviews those involved, undertakes any testing necessary, determines the root cause of the failure and the extent of the problem.
- Propose Corrective Actions to fix the full scope of the identified problem. This typically involves re-excavating the trench to a depth equal to the top of embedment plus one backfill layer and backfilling the trench using a Geotechnical Consultant's specified method. Where a test result is marginally outside of the specified limit (ie: <5% outside the moisture limit), dispensation may be sought and granted by the Water Agency for less or no remedial action to be undertaken.
- Propose Preventative Actions to reduce the risk of problems occurring again. This typically involves enhancing company processes, procedures, equipment and training to lift backfill performance.

Where the Contractor has evidence that another party (Consultant or other Contractor) is in some way responsible for the fault, this should be presented to the Water Agency so that they can take this into account during the review of the Contractor's non conformance response.

The investigation and the proposal describing the corrective and preventative action plans shall be completed within 15 working days of notification unless otherwise arranged with the Water Agency.

Once the Water Agency has reviewed and endorsed the proposed actions, the Contractor shall undertake the actions within an agreed date. Release and practical completion for the works (if not already awarded) would not normally be granted until all rectification works have been completed.

If the Contractor wishes to continue backfill construction works on the project while the Root Cause investigation is being undertaken, a revised procedure shall be agreed to by the Water Agency before work can continue.

7.4 Cost of Response

Where it has been established on review of the available evidence that the Contractor is at fault, all proposed corrective and preventative actions shall be undertaken at the cost of the Contractor.

Where the Water Agency has had to undertake emergency works to control a safety hazard associated with subsidence, all costs incurred during this emergency work shall be reimbursed to the Water Agency by the Contractor.

Where the asset is still under warranty and the Contractor has not taken reasonable steps to correct the subsidence event, the Water Agency may correct the subsidence and recover all costs from the warranty amount.

Where the asset is no longer under warranty and the Contractor has not taken reasonable steps to correct the subsidence event, this response will be taken into account in the Contractor's performance evaluations with the Water Agency.