PRACTICAL GUIDELINE FOR TRENCH REINSTATEMENTS IN THE ROAD RESERVE

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ABSTRACT

Trenches are regularly opened and reinstated in the road reserve by various utility companies. However, the knowledge of such utility companies regarding pavement materials and trench reinstatements can be inadequate. This paper has been written to assist the trench contractor and utility company in doing proper trench reinstatement in the road reserve. It is not suited to trench reinstatement in the road pavement. It synthesises road materials and construction knowledge and testing procedures to ensure trench reinstatement will meet end use and outcome requirements. Aspects such as soil and material knowledge, soil moisture estimation, compaction technique and measurement of bearing capacity have been re-packaged in plain English language to guide a non-road engineering person towards an acceptable and easily measurable outcome. Material description and moisture estimation are done using reliable visual description guidelines. Densification and bearing capacity achievement are guided without measuring actual density, but using instead the Dynamic Cone Penetrometer (DCP) or purpose developed Rapid Compaction Control Device (RCCD). A process and evaluation sheet is presented for quality control which is presented in a simplified format yet backed up by complex technical background information.

1 INTRODUCTION

Various utility companies make use of the road reserve to install their utility infrastructure in the road reserve. The utility companies normally have their own construction crew and equipment. However, their knowledge of road building materials and road layer construction can be lacking. The expectation from the road owner is always optimistic that trenches will be reinstated as per normal road building methodology and standards. This expectation is usually valid in the roadway itself, but the end use and functional requirements for a reinstated trench in the road reserve are quite different. Most of the services placement or positioning are in fact in the road reserve and the normal use may vary from a footway in urban areas to merely the grassed road reserve on a rural road. The trench reinstatement in the road reserve can therefore be done differently from those in the road itself.

This paper provides guidelines for trench reinstatements in the road reserve explained in plain English language. The information on methodology and technology is synthesised without needing an in-depth fundamental knowledge to achieve the required outcome. It does not address the issues regarding crossing other services, manholes or structures (e.g. bridges) as such cases are catered for via the road authority wayleave system and the required associated designs. It is not suitable for trench reinstatement in the road pavement. It focusses primarily on trench reinstatements for fibre optic cable, and their associated higher technical requirements for trench reinstatements, due to the high technical demand for such installations than the older utility technologies like, water, sewerage and electricity.

2. PERFORMANCE REQUIREMENTS FOR TRENCH REINSTATEMENT FOR FIBRE OPTIC CABLES

Fibre optic cables are installed in rural road reserves by using one of three trench digging technologies:

- Wide trench with a backhoe (back actor) digging (bucket 300 mm to 500 mm wide)
- Narrow shear plough type with automatic cable feed (e.g. spider plough type)
- Large blade/narrow trench (100 mm wide) (e.g. Vermeer type of cutting machines)

The trenching technologies all have different trench reinstatement methodologies. The wide trench/backhoe is the most common and is the most problematic in terms of reinstatement, and so this paper focuses on wide trench reinstatement.

The trench is typically dug to a depth of 1 metre. The fibre optic cable is usually buried in sand padding, sleeves and a protective concrete slab at the bottom of the trench. These are details which are the concern of the installer and is not dealt with here in any further detail The cable and its protection only occupy the bottom 200 mm to 300 mm of the open trench. The rest of the trench needs to be filled in and reinstated so that the fibre optic cable is still protected and the end result is acceptable to the road reserve owner such as SANRAL (South African National Roads Agency Limited).

SANRAL typically requires the end result after trench re-instatement in the road reserve to:

- be able to resist a load of at least 70 kPa i.e. equivalent to the load affected by a tractor pulling a grass cutting machine. Normally tractor tyre pressures must be 150 kPa to 200 kPa, therefore the higher value is applicable.
- must have a bearing capacity equivalent or better than the adjacent virgin soil.

Suitable materials for trench reinstatement are natural soil, gravel and crushed rock. The Technical Recommendation for Highways dealing with guidelines for road building materials (TRH 14, 1987) describes these materials using a variety of tests and qualities. Of these, bearing capacity is very important and materials are classified into one of 10 groups based on California Bearing Ratio (CBR). They range from G10 (weakest or lowest quality) to G4/G5/G6 (good quality natural gravel) to G1 (high quality crushed rock meeting stringent grading standards, etc.).

It is suggested that soil/gravel of classification G8 or better (G1 to G7) is required for the backfill material. Such a soil will carry the tractor wheel load described above (eThekwini, 2008). The following sections give simplified procedures to determine the material qualities of compacted reinstated trenches and ensure that G8 quality or better is achieved.

3. SIMPLIFIED SOIL DESCRIPTION

A basic soil description is useful to give insight into compaction efficiency and related control issues, as well as early material class range identification. This is less than the full description of soil in TRH 14, and is restricted here to three broad types based on visual evaluation:

1. ***Natural gravel and rock*** fill material (this may also imply going through rock that may need blasting to create the desired trench). This is any natural material which has a large percentage of stone; with rocks (larger than 20 mm diameter) and pebbles/gravel (smaller than 20 mm diameter) in the mix. It is highly likely that material with this identification will be G8 quality or better.
2. ***Gravel-natural soil*** typically associated with agricultural land. This material has some stones visible in the mix with soil rather than many; the stones can be a range of sizes and may include stones up to 20 mm diameter and larger. This material is also likely to be G8 quality or better.
3. ***Silty sandy clayey material***. This is a fine material with no or limited pebbles larger than say 5 mm present. It may tend to be very homogeneous and uniform in appearance. It may be characterised as getting weak when wet (in terms of bearing capacity) e.g. a truck getting stuck when wet. If there is much clay in the material, then it will have tell-tale shrinkage cracks when dry. It will also be much stronger in the dry than in the wet. These materials are less likely to be G8 quality and may even be worse (e.g G9 or G10).

It is suggested that the trench contractor keep a record of visual observations of the natural ground being traversed or over which trenching is done. It should be described in terms of the following two observations.

- **Visual surrounding soil condition**. This is mostly based on surface observations which give a good indication of the natural soil in the horizontal plane. This should be recorded as gravelly, natural soil/sand or clay.
- **Visual observation of the sides of the trench** being opened. This gives a good indication of the geological and soil variation in the vertical plane. The vertical may often differ from the horizontal description and should be recorded as rocky, gravelly, soil/sand or clay.

4. DENSITY MEASUREMENT FOR TRENCH REINSTATEMENT

In road building, the materials are compacted to improve bearing strength, and it is standard procedure to measure density of the compacted material when constructing road layers. Field density or insitu density of a compacted layer is an indirect indicator of real engineering properties like bearing capacity and effective elastic moduli. Density measured for road building material is normally a relative density expressed as a percentage of a sample compacted with a specific energy input in the laboratory, e.g % of Mod AASHTO or Proctor, etc. at optimum moisture content (TMH1, 1979).

Trench re-instatement in the road reserve deals with insitu or subgrade material, which can be very variable over even short distances. This implies frequent sampling and testing if the relative density approach is used, and this makes it impractical for trench reinstatement quality control. It is therefore proposed that bearing capacity of the compacted backfill material in the re-instated trench be measured directly as a practical means of quality control.

5. ENGINEERING PROPERTIES AND BEARING CAPACITY DETERMINATION

Sophisticated engineering properties such as elastic modulus can be measured using tools like Light Weight Deflectometer which measures deflection under a weight being dropped; the effective moduli can be back-calculated. (Horak and Emery, 2006; Horak et al, 2008). However this equipment is expensive and not yet adequately calibrated for subgrade material testing.
Instead the bearing capacity of the compacted backfill material in the re-instated trench can be measured in terms of California Bearing Ratio (CBR). This is an empirical relative bearing capacity measurement which is widely used in road engineering. CBR is always associated with a specific relative density and moisture condition (e.g. a CBR of 50 % at a density of 98 % Mod AASHTO, after soaking the material for 4 days). The soaked CBR value simulate the bearing capacity of the material in the worst possible environmental condition, when wet and soaked. Water in soil tends to reduce the bearing capacity significantly.

To avoid the complexity of laboratory testing, research and technology transfer work done in South Africa with the Dynamic Cone Penetrometer (DCP) provides calibrations and correlations with the field bearing capacity in terms of derived CBR values. The DCP also has the distinction that it has been extensively correlated and calibrated with accelerated road testing accurately with additional pavement performance and material behaviour descriptions. This makes this a very useful field evaluation tool. (De Beer, 1991 and Kleyn, 1982). The penetration rate for the DCP sounding through compacted layer(s) is determined and expressed in terms of mm/blow. The DCP result can be compared to TRH14 material classification shown in Table 1.

It must be noted that the DCP reading is dependent on actual moisture condition of the trench backfill, and the DCP reading should be adjusted according to the in situ moisture condition based on a definition of dry, moderate and wet. This definition of in situ moisture condition implies detailed material and laboratory testing which is addressed later in a simplified estimation approach. (De Beer, 1991 and Kleyn, 1982) The DCP rod is long and has the potential to penetrate and damage the fibre optic cables at the bottom of the trench. The DCP should therefore be restricted to shallow depths or a similar instrument used doing shallow soundings of bearing capacity determination.

The Rapid Compaction Control Device (RCCD) is a more purpose-fit bearing capacity measuring device, specifically developed for trench reinstatement (De Beer, Kolombo and Horak, 1993). It can be operated in the narrow confines of a trench by one person with ease and measures CBR values of a compacted layer. The basics and operation of the RCCD are graphically illustrated in Figure 1.

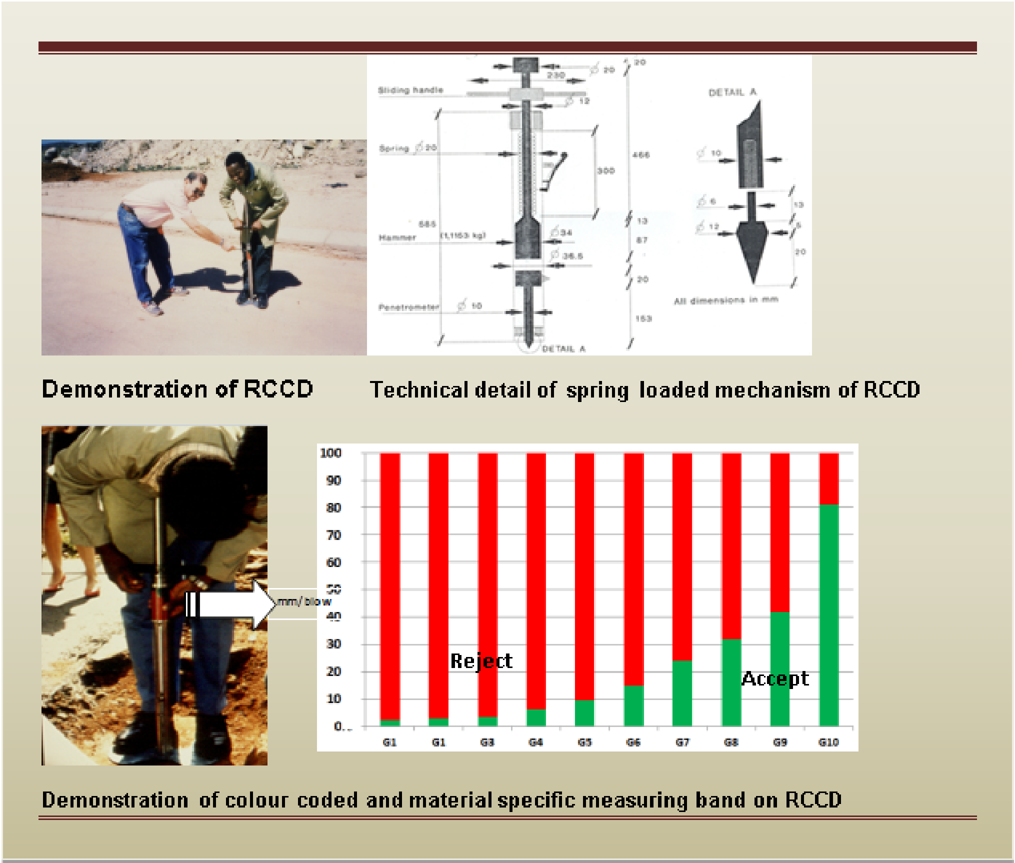

Figure 1 Rapid Compaction Control Device Illustration (De Beer et al, 1993)

The spring-loaded sharp point of the shaft penetrates the top 10 mm to 100 mm of a compacted layer to give a quick and repeatable indication of bearing capacity of a compacted layer. The RCCD is a scaled down version of the DCP. Instead of kinetic energy via the dropped weight, it uses a calibrated loaded spring to drive the pointed shaft into the compacted layer and thus measures in situ shear resistance, which is related to bearing capacity. The RCCD can be used to do repeated and accurate measurements of penetration after the prescribed three successive “shots” of the pointed shaft and CBR values can be derived from the laboratory derived correlations. The application here is to only determine the average penetration rate in terms of mm/blow.

The material class can then be determined using the penetration rate and the moisture condition of the backfill, as shown in Table 1. The moisture condition of the backfill will affect the penetration rate of a given material. Material which is weak, such as a G9 or G10, can be quite hard when dry, and so will have a “lowish” penetration rate when at optimum moisture content. Material which is strong, such as G1, will have a similar strength wet or dry, and the penetration rates will be similar whether soaked or at optimum moisture content (OMC) (Emery, 1988). The guiding RAG colours of Red (too weak), Amber (warning), Green (acceptable) have been superimposed on the Table 1.

Table 1 Material class summary with DCP and RCCD penetration rates

TRH14 code	Brief description	CBR range description as per TRH14 (%)	DCP Penetration rate (mm/blow)		RCCD* Penetration rate (mm/blow)
		soaked	soaked	OMC	OMC
G4	Natural gravel with specified grading	> 80	< 3.7	< 3.0	< 6.3
G5	Natural gravel with specified grading	> 45	< 5.7	< 3.8	< 9.7
G6	Natural gravel	> 25	< 9.1	< 4.7	< 15
G7	Natural gravel	> 15	< 14	< 5.9	< 24
G8	**Natural gravel or soil**	**> 10**	**< 19**	**< 7.1**	**< 32**
G9	Natural gravel or soil	> 7	< 25	< 8.1	< 42
G10	Natural gravel or soil	> 3	< 48	< 11	< 81

** The RCCD penetration is usually done directly after compaction done at OMC*

The RCCD may also be used in the rapid mode by using the colour calibrated measuring collar. This is done by setting the measuring cylinder of the RCCD to zero on the material type evaluated for (e.g G8) before the three shots. If the measuring staff is in the green zone, the bearing capacity for that material class has been achieved or bettered. If it is in the red zone (higher penetration rate), then the material is weaker than the required bearing capacity. No further calculations are necessary.

6. MOISTURE AS THE BACKFILL COMPACTION LUBRICANT

Moisture is usually added to the backfill gravel/soil to act as a lubrication agent, and it allows compaction and re-orientation of soil and aggregate particles to reduce the voids between them and increase density. Normally in a road pavement, the materials are allowed to dry out after compaction until a state of equilibrium moisture content (EMC) is reached which is a lower moisture content than optimum moisture content (OMC). At such a lower moisture content (e.g. EMC) the bearing capacity normally increase and therefore giving an incentive to keep pavement layers dry via water proof bituminous surfacings and subsoil drainage systems being installed.

Excess moisture is a problem because wet gravels and soils are weaker in bearing capacity capability. This is also true in trench reinstatements and therefore excess moisture should also be prevented. Excessive moisture in the backfill soil can be due to over-watering by the contractor, rain/stormwater or high water tables. The length of open trenches should be limited to short lengths, which is possible to be backfilled on the same day to prevent water intrusion. Where there is natural ground water, such as high water tables, vlei or low-lying areas, or even burst submerged water pipes, the trench must be kept dry by means of pumping or additional drainage. Cement stabilization of the backfill is often used in such cases.

Overly wet material must be allowed to dry out before backfilling is attempted. To monitor the insitu moisture content to determine how close it is to the optimum moisture content (OMC) for practical and efficient compaction effort, a simplified moisture classification is given in Table 2 based on basic material descriptions. The RAG (Red for unacceptably wet or dry, Amber for marginally close to OMC and Green for OMC range) condition system is superimposed for guidance. An alternative to drying the backfill is to use drier, better quality material (e.g. G5 to G3), but this has cost implications. This visual estimation of in situ moisture is also appropriate to determine the necessary adjustments to the values obtained from the DCP when in situ bearing capacity is determined. This is typically necessary when the trench reinstatement bearing capacity needs to be compared with the surrounding soil as set out in the performance requirement

Table 2. Simplified visual and physical moisture rating description

Moisture description	Soil description		
	Natural Gravel	**Gravelly Soil**	**Clay and silt**
Dry	Gravel and aggregates are loose with ***no visible sign or glistening of moisture*** present and possible dustiness when squeezed in hand finer material may cling to aggregates as hard clumps.	General impression is dry handled with **no visible sign or glistening of moisture** present. Finer material may form hard clumps and may come from aggregates and pebbles if pinched between thumb and index finger in pincher move	Clumps appear dusty and hard to break with thumb and index finger. ***No visible sign or glistening of moisture***. If it breaks it crumbles into dry smaller clumps.
Slightly moist	A ***slight glistening*** may be seen of freshly exposed faces and ***a colour change to the material may be observable***. The finer material may form clumps or a ball when squeezed in hand palm, breaks virtually immediately after release of pressure. **Moisture is below optimum moisture content**	A **slight glistening** may be seen of freshly exposed faces and ***a colour change to the material may be observable***. The finer material may form clumps or a ball when squeezed in hand palm. Breaks but may crumble on its own very soon when hand pressure is released***. Moisture is below optimum moisture content***	A ***slight glistening*** may be seen of freshly exposed faces and ***a colour change to the material may be observable***. The finer material may form clumps or a ball when squeezed in hand palm. Breaks relatively quickly on own when hand pressure is released. ***Moisture is below optimum moisture content***
Moist (optimum moisture content)	**A glistening and colour change may be observable** on freshly exposed faces. Pressure with a thumb may leave a moist impression on thumb. Fines from mix may hold a ball form with a plastic consistency when squeezed in palm of hand. Squeezed ball may hold form for a while after palm pressure release. Large aggregates may also stick to rest of matrix when sampled and squeezed. Moisture is ***close to optimum moisture content.***	A ***glistening and colour change may be observable*** on freshly exposed faces. Pressure with a thumb may leave a moist impression on thumb. Fines from mix may hold a ball form with a plastic consistency when squeezed in palm of hand. Squeezed ball may hold form for a while after palm pressure release. Aggregates and pebbles may also stick to rest of matrix when sampled and squeezed. Moisture is ***close to optimum moisture content***.	A ***glistening and colour change may be observable*** on freshly exposed faces. Pressure with a thumb may leave a moist impression on thumb. Material may hold a ball form with a plastic consistency when squeezed in palm of hand. Squeezed ball may hold form after palm pressure release. Will feel relatively clayey in hand. Moisture is ***close to optimum moisture content.***
Very Moist	A definite ***glistening will be observable*** on freshly exposed faces. Pressure with a thumb may leave a wet impression on thumb. Fines from mix may hold a ball in a relatively plastic to liquid consistency when squeezed in palm of hand. Squeezed ball may hold form for a while after palm pressure release with ***wetness felt and observed in palm***. Large aggregates may also stick to rest of matrix when sampled and squeezed, but squeezed ball will tend to fall apart after short while. Moisture is above optimum water content.	A definite ***glistening will be observable*** on freshly exposed faces. Pressure with a thumb may leave a wet impression on thumb. Fines from mix may hold a ball form in a relatively plastic to liquid consistency when squeezed in palm of hand. Squeezed ball may hold form for a while after palm pressure release with ***wetness felt and observed in palm***. Aggregates and pebbles may also stick to rest of matrix when sampled and squeezed, but squeezed ball will tend to fall apart after short while. Moisture is above optimum water content	A definite ***glistening will be observable*** on freshly exposed faces. Pressure with a thumb may leave a wet impression on thumb. Material may hold a ball form in a relatively plastic to liquid consistency when squeezed in palm of hand. Squeezed ball may hold form for a while after palm pressure release with ***wetness felt and observed in palm***. Squeezed ball will tend to fall apart after short while. Moisture is above optimum water content
Wet and saturated	***Definite glistening or even water oozing*** from freshly exposed faces with water oozing from soil matrix. Will feel definitely wet when handled with water squeezing out if hand palm pressure is applied in forming a ball. Will tend to break immediately when released from hand and aggregates will tend to segregate and fines drip through fingers in soupy consistency.	***Definite glistening or water oozing*** from freshly exposed faces with water oozing from soil matrix. Will feel definitely wet when handled with water squeezing out if hand palm pressure is applied in forming a ball. Will tend to break immediately when released from hand and aggregates will tend to segregate hand and aggregates will tend to segregate and drip through fingers in soupy consistency.	***Definite glistening or water oozing*** from freshly exposed faces with water oozing from soil matrix. Will feel definitely wet when handled with water squeezing out if hand palm pressure is applied in forming a ball. Will tend to break immediately when released from hand and will tend to segregate and drip through fingers with fine soupy consistency.

7. PROPOSED QUALITY ASSURANCE AND CONTROL PROCEDURE

The simplified guidance towards effective trench reinstatement in the road reserve also needs a simplified process for quality assurance, proper recording and client approval purposes. The proposed methodology recognises the important influence of backfill moisture content on bearing capacity. The backfill should be allowed to dry out to equilibrium moisture content (EMC) when the bearing capacity is also reaching its optimum. Therefore observations and control should be done after a period of at least two weeks after backfilling to allow for such drying out and associated improvement of bearing capacity.

In its simplest form the reinstated length of trench will be evaluated in a three step process regarding the end use acceptance control and can thus be applied in a three levelled or phased approach:

- The first level is that of visual observations. The visual observations should look at the condition of the reinstated trench as to whether it shows any signs of settlement, erosion or even when stepping onto it whether you sink into the trench when stepping onto it.
- The second level of the outcome or performance specification is to do a simple performance test, the “tractor test”. It is used as comparison to ensure the clearly stated outcome is reached to ensure the grass can be cut on the reinstated verge. A tractor or a bakkie (of at least 1 tonne) is driven with one side of the wheels on the reinstated trench as well as on the reinstated trench and the indentations are compared. This is clearly a proof test and can only be done if the topography and access allows for it. Even just walking on the reinstated trench will already give an early indication of achieved bearing capacity. In the worst case sinking into the reinstated trench is an extreme indication of lack of compaction and bearing capacity.
- The third level of acceptance control and testing should be done over and above the first two levels of testing as a higher order test to compare the bearing capacity of the reinstated trench with its undisturbed surroundings. The measurement of bearing capacity of the re-instated trench and comparison with the in situ bearing capacity or reference material class can be done on top of the surface with the DCP or the RCCD. The material classification via the penetration rate derived CBR determination from Table 1 is used. The RCCD is favoured as control device because of the ease of operation and lesser probability of damaging the cables below.

The bearing capacity of a G8 material is used as reference as it can carry the 70 kPa of the tractor. The simplified recording and approval form is shown on the next page. It makes use of the RAG (Red, Amber and Green) criteria for respectively reject, provisional acceptance and acceptance. The levels 6 and 7 deal with observation of insitu moisture evaluation and the description of the local topography as both have a significant influence on the performance of the bearing capacity.

Table 2. Proposed simplified trench reinstatement quality control form

<table>
<tr><td colspan="6">Recording Form for Trench Re-instatement: Date Recorder Signature</td></tr>
<tr><td colspan="6">Section description: e.g N214 km left hand side road reserve km 14.5 to km14.6</td></tr>
<tr><td colspan="2">1.Visual survey (tick)</td><td>Reinstated trench top standing proud</td><td>Reinstated trench top level with surroundings</td><td>Reinstated trench top showing settlement of less than 10 mm</td><td>Reinstated trench top showing settlement of more than 20mm</td></tr>
<tr><td colspan="2">2. “Tractor Test” Drive with tractor or at least 1 tonne bakkie on the reinstated trench) (Tick)</td><td>No indentation</td><td>Slight indentation</td><td>Indentation more than 20 mm</td><td>Deep indentation more than 50 mm</td></tr>
<tr><td colspan="2">3. RCCD or DCP penetration rate (mm/blow) on surrounding material and the top of backfill (average of 4 tests every 100 m)

* Determine material class from Table 1</td><td>1. Surrounding
e.g. RCCD (20 mm/blow), G7
Trench
e.g. RCCD (12 mm/blow), G6</td><td>Surrounding
e.g. RCCD (25 mm/blow), G8
Trench
e.g. RCCD (26 mm/blow), G8</td><td>Surrounding
e.g. RCCD (20 mm/blow), G7
Trench
e.g. RCCD (30 mm/blow), G8</td><td>Surrounding
e.g. RCCD (27 mm/blow), G8
Trench
e.g. RCCD (37 mm/blow), G9</td></tr>
<tr><td colspan="2">4. Derived material class of reinstated trench top (Tick)</td><td>G4 to G6</td><td>G7 to G8</td><td>G9</td><td>G9 to G10</td></tr>
<tr><td colspan="2">5. Comparison of backfill with natural surrounding ground (Tick)</td><td>Better, and better than G8</td><td>Better, and better than or at least equal to G8</td><td>Less than surroundings but still better or equal to G8</td><td>Less than G8 and less than surroundings</td></tr>
<tr><td>6. Moisture description of surrounding material and trench (Tick)</td><td>Dry</td><td>Slightly moist</td><td>Moist</td><td>Very moist</td><td>Wet saturated</td></tr>
<tr><td colspan="2">7. Local topography description (Tick)</td><td colspan="2">Level
Low point
Top of local rise
Gradual incline
Steep incline</td><td>Local drainage description (Tick)</td><td>Level,
Potential for local ponding
Potential for erosion due to gradient
Furrow to enable drainage away
Other (describe) ……….</td></tr>
<tr><td colspan="2">6.Acceptance (tick)</td><td colspan="2">Yes</td><td>Conditional acceptance</td><td>Reject</td></tr>
<tr><td colspan="2">Signed off by client representative</td><td colspan="2">Name</td><td>Signature</td><td>Date</td></tr>
<tr><td colspan="2">Additional comments</td><td colspan="4"></td></tr>
</table>

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