A9 Berriedale Braes Improvement

Geotechnical, Design and Construction Assessment

July 2011




Prepared for

TRANSPORT SCOTLAND

Revision Schedule

Geotechnical, Design and Construction Assessment
July 2011

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1 Introduction

Berriedale Braes lies on the A9 Trunk Road to the north of Helmsdale and to the south of Dunbeath. The location is shown on Figure 1 and Plates 1 and 2 provide aerial photographs of the area.

The road alignment at this location has developed over many years and consequently the geometry is sub-standard when assessed to modern design standards. The terrain is demanding and the road geometry includes a number of tight bends and steep gradients as the road crosses the valley containing the Berriedale and Langwell Waters adjacent to the village of Berriedale.

Approximately 1km north of the Berriedale village the A9 drops from an elevation of over 150 mAOD to 20 mAOD as it enters the valley. Gradients of approximately 13% are required to achieve this change in level and on the north side of the valley a hairpin bend, with a radius of approximately 10 metres, has been introduced in order to achieve the change in level within the topographical constraints.

Heavy goods vehicles travelling in either direction take up the whole of the carriageway whilst negotiating the hairpin bend and consequently opposing traffic has to slow down or stop to avoid collisions. When northbound HGVs give way to southbound traffic they are forced to stop and execute a hill start on a very steep gradient; this is a difficult and potentially dangerous manoeuvre due to the weight re-distribution from front to rear axle of the tractor unit. In May 2010 a coach travelling south ran into the safety barriers after its brakes on the steep downhill just before the hairpin bend..

1.1 Previous Work

Previous work carried out by Acer in 1991 examined the possibility of providing a viaduct structure to improve the geometry at this location. The viaduct was costed at £10.3 million at 1991 prices including VAT so did not proceed, on cost grounds.

In 2004, as part of the maintenance works, a commission was let to investigate the use of “smart” technology to allow northbound HGVs to continue their journeys unimpeded, by using traffic signals to stop southbound traffic. Initially there was broad local support for the proposed signals but through time this changed until the implementation of the traffic signals was opposed by The Highland Council. The ducting and loops were installed during other works. The infrastructure for the installation of the traffic signals remains in place and would only require the installation of the signals and associated cables, traffic signs and road markings to implement the scheme. The cost of completing this work has been estimated at £40,000.

In November 2006 Scott Wilson (now URS/Scott Wilson) prepared a report on three possible options for improvements to the A9 at Berriedale Braes. Since that report the improvement of the A9 at Berriedale was included in the Strategic Transport Projects Review in 2008 but it was not one of the projects to be taken forward at that time.

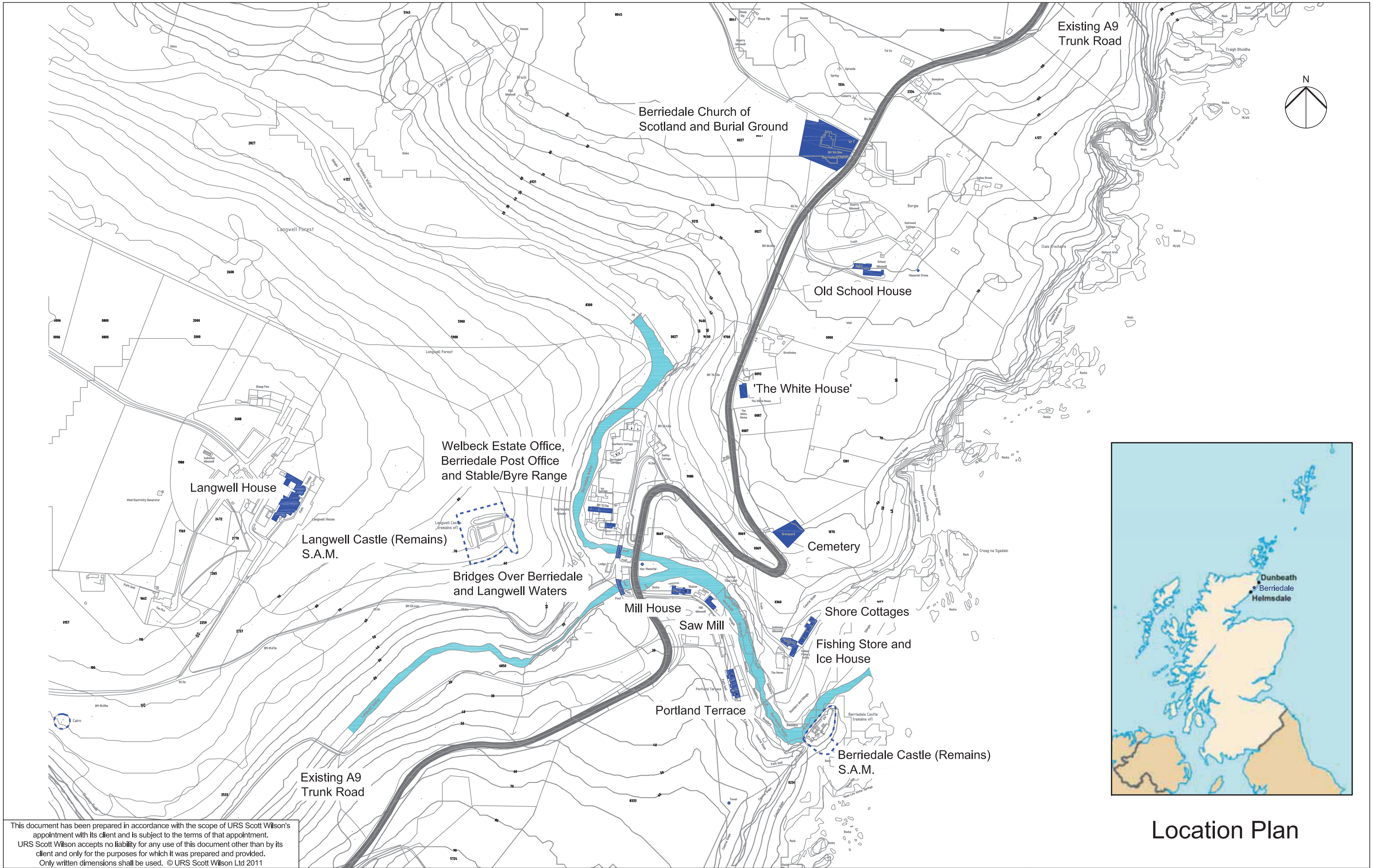
In 2008 Wellbeck Estates, the owners of the land surrounding the A9 at Berriedale, produced a report which identified a much shorter option for the re-alignment of the hairpin bend and also considered a local widening option.

1.2 Current Situation

In 2010 The Highland Council continued to have concerns on the safety of the existing road and continued to press for improvements of the road. As such Transport Scotland (TS) now wish to examine whether the fitting roads approach used for the design of the A9 at Helmsdale can be adopted to support any of the solutions identified by URS/Scott Wilson (URS/SW) and Wellbeck Estates at Berriedale Braes. URS/SW were commissioned to

- Review the two alignments proposed by URS/SW and Wellbeck Estates and discuss with Standards Branch to ascertain the most acceptable standards to be adopted and hence route corridor for the survey.
- Prepare and procure a geotechnical investigation of the routes including site and all reporting works. TS also requested that investigation be undertaken to consider the feasibility of the local widening option.
- Provide a summary report of the findings including design standards, alignment and geotechnical investigation.

This report 'Geotechnical, Design and Construction Assessment' presents the findings of the work carried out between January and April 2011..



Location Plan

Plot Date :
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A9 BERRIEDALE BRAES IMPROVEMENTS
GEOTECHNICAL, DESIGN AND CONSTRUCTION ASSESSMENT

LOCATION PLAN

FIGURE 1

Scale at A3 : 1:5000		
Drw RM	App AB	Rev -
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DB3

Plate 1 - Aerial Photograph of Berriedale from the East

Plate 2 - Aerial Photograph of Berriedale from the West

2 Road Geometry

2.1 Existing Road Geometry

The existing carriageway consists of steep gradients of up to 13% and substandard horizontal geometry including a hairpin bend of 10m radius. On the northbound approach to the hairpin there is a series of low radius bends, of 50m, 80m and 30m respectively, which in combination with the steep gradients serve to slow traffic speed. Heading north from the hairpin bend the horizontal geometry improves slightly with a series of 120m radius bends and short straight sections.

2.1.1 Design Target

The "Fitting Roads" design principle has been applied to develop the scheme design. An analysis of the road type, the hierarchy, the road users, its potential use and the adjourning road design standards resulted in bench marking the design against the A9 Helmsdale to Ord of Caithness Improvements. A meeting was held on 3 February 2011 with Neil Wands of Transport Scotland (Standard Branch) and URS/SW and the following the target design was agreed :

- Design Speed of 85kph
- Minimum carriageway width of 6.0m
- 1.0m hard strip
- 1.65m minimum soft verges (2.65m verge width, including hard strip)
- Widening on curves as per DMRB

Target SSD of 70m or greater if possible without incurring significant economic and environmental impact, or 50m if this is not possible. I.e. 3 or 4 steps below for 85kph design speed, or less where possible.

2.2 Proposed Road Geometry

The current work followed Option 2 in the work done in 2006 by URS/SW and the main option proposed in 2008 by Wellbeck Estates. The two alignments proposed were similar and both were assessed and an optimum design prepared to fulfil both concepts. Hence only one design has been considered in this report. This is shown in Figure 2.

A further local improvement of the hair-pin bend can be considered if this is thought to be advantageous. This would involve some complex geotechnical work to support the existing burial ground/grave yard site and has not been considered in the discussion on roads design below. However one trial pit was carried out to look at the geotechnical aspects and this is discussed in section 8 of the report. An alignment can be developed if this option is to be take further, but the relative costs of this may out weigh any perceived cost saving on the more extensive option considered in this report.

The design model used for the preliminary design has been prepared based on the Ordinance Survey contours and is considered to be adequate for this preliminary work. It is suggested that a more detailed topographical survey is carried out if the project is taken to detailed design, and this is discussed below in paragraph 10.0.

The Figure 2 shows the proposed design. This has adopted slopes of 1:1 for embankments slopes on the seaward side due to the steep gradients on the hill below. This would require some form of reinforced soil, soil nails or a retaining structure and is the major challenge to the construction of this design.

Elsewhere embankment slopes of 1:2 have been adopted.

In cuttings slopes at 1:2 have also been proposed in soil slopes. Based on the preliminary information from the ground investigation, there is the potential to increase these slopes to 2:1 where rock has been encountered and this is shown at chainages 200 to 280 approximately.

2.2.1 Horizontal Alignment

The proposed alignment eliminates the hairpin bend by replacing it with a 55m radius curve to match the existing road geometry on both approaches. The alignment then continues straight leading into a right hand curve of 120m radius as it ties into the existing road. This geometry is substandard for the design speed of 85kph and departures from standard are discussed below. Appropriate curve widening has been applied in accordance with the DMRB.

While the horizontal alignment is substandard it should be noted that this represents an improvement on safety and level of service from the current condition.

2.2.2 Vertical Alignment

The maximum gradient remains at 14% around the 55m radius bend however this is only a very short distance situated on a crest curve. The gradients are non standard over a distance of approximately 180m ranging from 8% to the maximum of 14%. For the remainder of the alignment the gradient drops steadily to a minimum of around 4%.

Both crest and sag curves used in the alignment are substandard for the design speed of 85kph.

2.2.3 Cross Section

The design target will be achieved for the cross section of the road including the widened part of the curve.

To achieve the designed parameters a retaining wall or some form of slope reinforcement will be needed over the first 100m on the seaward side of the 55m radius bend. A 1:2 cut is used to the north of the alignment and this avoids encroachment into the existing graveyard. A box cut is shown for this alignment however this can be eliminated by using 1:8 side slopes on the seaward side of the road to prevent snow drifting, if this is considered necessary. However this will have an obvious impact on the environmental and financial cost of the scheme.

2.2.4 Departures from Standards

The following Departures from standards have been identified

- Gradient: All gradients above 8% are considered to be a Departure from Standards.
- Vertical curvature: Crest curve is two steps below the desirable minimum (K=17) for the design speed of 85kph.
- Vertical curvature: Sag curve (K=13) is one step below the absolute minimum for a design speed of 85kph.
- Horizontal Curvature: Five and six steps below the desirable minimum of 510m radius for a design speed of 85kph for the 55m and 120m bends respectively.
- Driver Visibility: Visibility of 70m can be achieved by introducing a widened verge around the 55m radius bend, three steps below the desirable minimum for a design speed of 85kph. This may be reduced to 50m if the widening of the verge is considered to have too great an impact on the environmental and financial cost of the scheme. Whilst this would still be a vast improvement on the current geometry, it will be four steps below the desirable minimum for a design speed of 85kph.

2.3 Cost Estimate for the Proposed Scheme

Based on the alignment indicated in Figure 2 an estimate of the construction cost has been prepared and this has been used to provide an estimate of the. This has been based on 2008 prices inflated to 2011 by using a factor of 3.5% per annum inflation rate and includes a 25% optimism bias.

A Scheme Cost of £2.3M has been calculated based on the above.

3 Existing Information

3.1 Topography

OS mapping shows that the topography of the site varies from steep cliff-side slopes in the south (Ch 0m to Ch 200m) to flat pasture land at the north (Ch 200 to Ch 500m). The existing A9 bounds the site to the west and the sea cliffs lie to the east.

The Berriedale Water follows its course to the sea in a steep sided valley to the south and east of the site.

At the local widening option a steep bracken covered slope lies between the cemetery boundary wall and the existing retaining wall which runs along the southbound carriageway of the A9.

3.2 Geology

3.2.1 Superficial Geology

The superficial geology is shown on British Geological Survey (BGS) Scotland Sheet 110 as being Boulder Clay (Glacial). Also, the online BGS GeoIndex indicates that the superficial geology is Till (Devensian - Diamicton).

Devensian is the age in which the till was deposited ie. the most recent ice age. A study of the geology of the area suggests that historically there has always been a bay at Berriedale and it is likely that a pre-glacial channel existed along the path of the current Berriedale Water, taking water and sediments to the bay from inland. When glaciers moved across the area they would have deposited material into this existing channel. With subsequent glaciations more material would be deposited in layers above the channel and across the surrounding rock headlands. After the glaciers retreated the till has been eroded away, but is likely to be deeper close to the Berriedale Water, along the conjectured course of the in-filled pre-glacial

The term ‘Diamicton’ refers to the nature of the material. It is defined as a ‘poorly sorted sediment with larger grains (gravel size and larger, greater than or equal to 2 mm) set in a matrix of fine grains’.

Rock outcrops are visible towards the higher central point of the site. Where the rockhead is shallow weathered rock may be encountered in the form of sands and gravels with occasional/frequent fragments of the parent rock.

3.2.2 Solid Geology

The solid geology is shown on the BGS Scotland Sheet 110 as being Berriedale Flagstones. Online the BGS GeoIndex indicates that the solid geology is the Berriedale Sandstone Formation comprising sandstones siltstones and Mudstones, part of the Lower Caithness Flagstone sub-group and the Middle Old Red Sandstones.

The Berriedale Fault is shown to run east –west to the north of the site. It can be seen on the ground surface as a cleft in the fields to the east of the farmhouse. The BSG map shows the Berriedale sandstones lie to the north of the fault and Berridale Flagstones are present to the south.

The shoreline of the Berriedale area once formed part of the Orcadian lake that encompassed the Moray Firth area and it is thought that an embayment on the SW margins of the basin existed at Berriedale. Fluvio-lacustrine sediments and alluvium were laid down in the bay in the Devonian era and have formed what are now the Berriedale flagstones and sandstones. The flagstones comprise the finer fluvio-lacustrine sediments with the underlying coarser alluvials now forming the sandstones. The existing shoreline cliff geology is shown in Photo 3.1 below.

The variation in grain size between the fluvio-lacustrine deposits and the alluvial deposits translates into thinner bedding layers in the Berriedale Flagstones than would be expected in the Sandstones.

Photo 3.1 Cliffs along the shoreline below Berriedale Braes

The Berriedale Braes cliffs are a Site of Special Scientific Interest (SSSI) and it is noted by Scottish Natural Heritage (SNH) that some of the geology at the Berriedale cliffs shows processes which occur on submarine slopes because these deposits used to be submerged beneath sea level. Boulder Beds formed from Middle Red Sandstone suggest there were avalanches of coastal debris into deep water at this site about 150 million years ago.

3.3 Mines and Mineral Deposits

No records have been found of mining or mineral extraction at the site. A small disused quarry lies approx half a kilometre to the north of the site where the rock outcrops close to the A9.

3.4 Land use and Soil survey

The land use varies across the site. In the south the site is located close to the steep cliff-side slopes. The land is currently covered in dense bracken and is un-used by the landowner. The cemetery lies on high ground above the cliff-side slopes. The north of the site is flat pasture land used for cattle grazing. At the northern tie in with the A9 residential properties are present in the form of the White House and a farm building.

3.5 Groundwater

The Hydrogeological Map of Scotland shows that the geology underlying the site is classed as an aquifer in which flow is dominantly in fissures and other discontinuities; a locally important aquifer (as opposed to highly productive or limited potential). In Caithness the groundwater is noted to be “confined to the upper shallow zone of weathered rock and borehole yields are minimal”.

The Groundwater Vulnerability Map of Scotland shows that the geology is classed as moderately permeable. The map noted that that there is likely to be a low permeability drift deposit overlying the solid geology.

3.6 Archaeological and Historical Investigations

Historical maps show that the area has been in a similar condition since 1877 with the cemetery and the road being the main man-made features. Dates on headstones in the graveyard suggest that it has existed since the early 1800’s with the most recent burial being in 1934.

The road has two substantial retaining walls at the hairpin bend. Structural inspection records held by Transport Scotland suggest that the retaining walls are mass concrete gravity retaining walls built around 1820.

To the south east of the cemetery lower down on the cliff-side slopes and directly under the footprint of the re-alignment route there is a small structure shown on historical maps. Evidence of the structure is present to this day in the form of relic stone walls and it is noted in RCHAMS records as an 'unroofed structure'.

The White House (an old manse) at the northern tie-in is a listed traditional building.

3.7 Contaminated Land

Based on the historical mapping and a site walkover the potential conditions are summarised as follows. The cemetery is a source of possible contamination, however as there have been no recent burials (during a site walkover, the most recent headstone appeared to be dated around 1930) and the underlying soil is reasonably permeable (sands, clayey sands) it is unlikely that there are still significant concentrations of contaminants from burials at the cemetery leaching through the ground[1].

Owing to the quality of the pasture land, diffuse contamination in the form of pesticides and farm chemicals are considered unlikely.

At the tie-in to the A9, contaminants relating to the current road use and previous road and retaining wall construction may be present.

3.8 Ecology and Environment

The cliffs to the east of the site are part of the East Caithness Sea Cliffs Site of Special Scientific Interest (SSSI). In addition the cliffs have Special Protection Areas (SPA) and Special Area of Conservation (SAC) classification.

An ecology walkover was undertaken prior to the ground investigation site works. During the ecology walkover survey it became apparent that the site of the GI works (excluding the pasture field) contained a number of habitats, which potentially could be of conservation interest i.e. acidic / coastal grassland and may subsequently support a number of protected / biodiversity action plan species i.e. Adder.

Due to the close proximity of the works to the SPA & SAC, it is recommended that Scottish Natural Heritage (SNH) is consulted about the developing scheme, in particular prior to any further site works, as future works may disturb nesting sea birds, which are a qualifying feature of the SPA.

No evidence of badgers was recorded i.e. setts or other field signs within the study area. However, given the extent of dense gorse on site, the presence of badgers cannot be totally ruled out.

[1] In accordance with Assessing the Groundwater Pollution Potential of Cemetery Developments (EA, April 2004), less than 0.1 per cent of the original loading from human corpses may remain after 10 years.

4 Field and Laboratory Studies

4.1 Ground investigation

Ground investigation works carried out as part of this assessment work are shown on Figure 3 – 2011 Ground Investigation Layout Plan. The site works of sixteen trial pits were carried out between 16 and 18 February 2011 using a Volvo ECR88 tracked excavator.

Fifteen of these were completed along the length of the proposed re-alignment as part of a preliminary assessment. The trial pits were excavated to depths of 0.5m to 4m to obtain samples for laboratory testing, to allow inspection of the underlying ground conditions and to establish depths to bedrock. Some geo-environmental samples were also recovered. In-situ testing was not undertaken.

A further trial pit (TP16) was undertaken between the cemetery and the existing roadside retaining wall to gain geotechnical and geo-environmental information for the local widening option.

The trial pit logs are included in Appendix 1 of this report.

4.2 Walkover Survey

In addition to the trial pits a walkover survey of the southern part of the site was undertaken to assess the condition of the cliff-side slopes and identify any evidence of historic or current instability. An annotated plan summarising the main features of the cliff-side slopes is provided in Section 5.1 and the observations during the survey are included in Section 5.2.1.

4.3 Rock Face Inspections

Finally, as rock was encountered in the trial pitting inspections of exposed rock faces near the site were undertaken to gain information about the type and nature of the rock underlying the site. Two rock faces were inspected; a rock cut face along the northbound A9 immediately south of the hairpin bend, and the shoreline cliff face below Ch 50m to Ch 150m of the re-alignment option.

The rock face inspection records are included in Section 6.5.1.

4.4 Laboratory Testing

Laboratory testing was undertaken by Soil Engineering Ltd on the soil samples obtained during the trial pitting. The following tests were undertaken on the soil samples:

- Classification tests: particle size distribution, moisture content, Atterberg limits, particle density
- Compaction and re-use tests: Proctor test, California Bearing Ratio (soaked and at natural moisture content), MCV (single point and calibration ine)
- Chemical tests: pH, BRE SD1 tests for aggressivity

Selected soils were sampled for environmental purposes and sent by Soil Engineering Ltd to Scientific Analysis Laboratories in East Kibride for testing of the following chemicals[2]:

- pH and BRE SD1 tests on soil samples for aggressivity
- Heavy metals, hydrocarbons (total petroleum hydrocarbons and TPH CWG), volatile organic compounds (VOCs), sulphates, total phenols, asbestos fibres, soil organic matter

Rock samples were obtained both during trial pitting (from rock fragments excavated from the base of trial pits) and from the exposed rock faces in the vicinity of the site. The following tests were undertaken by MatTest on the rock samples:

- Point Load index tests (Irregular Lump Tests) (ISRM)
- Resistance to Fragmentation by the Los Angeles test method (BS EN 1097-2:2010, Clause 5)
- Magnesium Sulfate Soundness test (BS EN 1367-2:2009)
- Water Absorption – wire basket test (BS EN:1097-6:2000)

[2] SAL is UKAS accredited holding accreditation for the majority of chemical tests performed.

5 Ground Conditions Summary

Ground conditions were found to vary considerably along the site. For each re-alignment option the ground conditions encountered during the trial pitting are summarised below:

5.1 Local Widening Option

The single trial pit excavated for this option (TP16) extended to 4mbgl with no signs of rockhead or weathered rock. The ground encountered was a brown slightly clayey gravelly SAND over a grey slightly gravely clayey SAND (which had a strong odour of fuel/hydrocarbons, further details are provided in Section 8). Below 2m bgl the strata became a gravelly clayey silty SAND. This is similar to the ground conditions underlying Ch 0m to Ch 180m of the re-alignment option.

Seepages on the uphill (north) face were recorded at 1.2m bgl and the sand from 1.1m to 2.6m bgl was noted to be very damp. Below 2.6m no groundwater was encountered.

5.2 Re-alignment Option

5.2.1 Ch 0 – 170m

At the southern part of the proposed re-alignment between 2m to 2.4m of grey damp silty clayey gravelly SAND was encountered overlying a denser drier dark brown very gravelly silty clayey SAND to 4m bgl. Rock was not encountered in the trial pits although the ground became more difficult to excavate with depth.

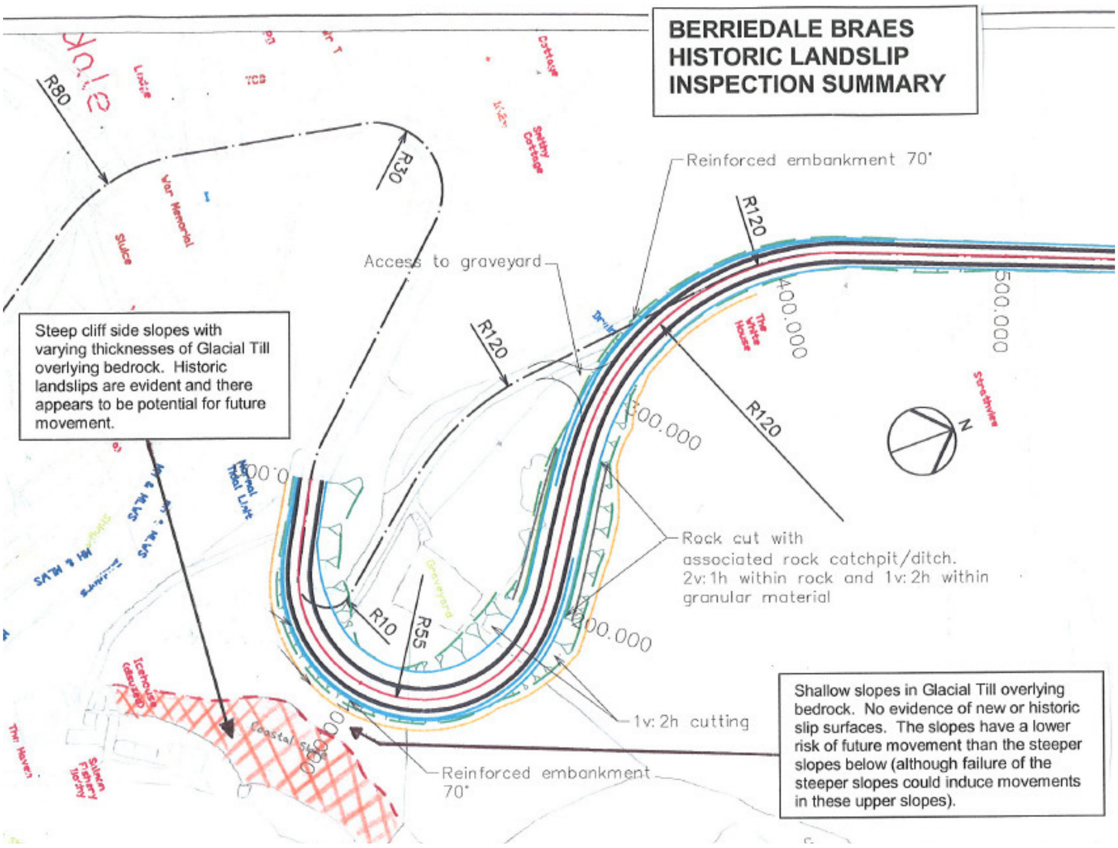
Slight seepages were recorded at various depths between 1m and 2.4m bgl in the upper grey gravelly silty clayey SAND strata. The underlying sand was generally dry apart from seepage observed at 3.5m bgl in TP12.

This part of the site lies on land that slopes towards the coast. There are no cliffs at the toe of the slope and the potential for historic landslips has been noted in the Wellbeck report and the Scottish Natural Heritage information. An engineering inspection was undertaken to assess the condition of the existing cliff-side slopes and determine the potential for future movements. Figure 5.1 (see below) summarises the findings of the inspection.

Furthest from the re-alignment there are the steep cliff-side slopes which are highlighted on Figure 5.1 as red hatching. The OS mapping notes the area as 'Coastal Slopes'. These slopes appear to have been shaped by historic slip failures as the Glacial till, sitting on the bedrock at a steeper profile than its effective angle of repose can sustain, has slipped down towards the shoreline. The recent slope inspection found rabbit burrows, bare soil scars, very damp soil and hydrophilic vegetation, all indicators of potential for future slope instability. There was no recent spoil evident along the shoreline at the toe of the slope.

Behind the steep 'coastal slopes' and directly under the re-alignment, the topography relaxes and the slopes lies at shallower inclinations. The area resembles a shallow bowl-shape. On a line with the unroofed structure, there is a step in the slope of approx 0.5m high that follows the contours round to the hairpin bend, a levelled out area looking like an old access runs on this stepped area. If this is not a man made feature then it may be a relic back-scar and the bowl-like shape may be indicative of past slope movement.

Figure 5.1 Historic Landslip Inspection Summary



5.2.2 Ch 170 – 210m

This area forms a transition between the ground conditions along the cliff-side slope and those of the plateau and rock outcrops further north. The upper 2m to 3m of the ground was a very gravelly silty clayey SAND/very sandy silty clayey GRAVEL overlying a silty slightly clayey SAND/GRAVEL. The gravels were noted to be angular and of reddish sandstone, similar in appearance to rock exposed in the cliff faces along the shoreline below the site.

Slight seepages were recorded in the uphill faces of TP11 and TP10 at depths of 1m, 2.5m and 3.5m bgl.

5.2.3 Ch 210 – 280m

Shallow rock was encountered beneath this part of the route, at depths of between 0.5 and 1.4m bgl. The rock type was a flaggy red sandstone that was recovered as angular to sub-angular boulder and cobble sized slabs.

Groundwater was not encountered in the trial pits along this part of the route. However, groundwater may be present in joints and fissures within the rock mass at depth.

5.2.4 Ch 280 – Ch 350m

Superficial deposits of very gravelly silty clayey SAND, very sandy silty clayey GRAVEL and clayey SAND/GRAVEL were again found to depths of 3.3m bgl. Rock was not encountered although the ground became more difficult to excavate with depth.

A slight seepage was noted in TP01 at 0.65mbgl on the uphill face, no further groundwater was recorded.

5.2.5 Ch 350 – 500m

Ground investigation was not undertaken at this part of the re-alignment. However, the ground to the west of the existing A9 is noted to be a plateau covered in hydrophilic vegetation above a steep rock slope leading down to the Berriedale Water.

6 Ground Conditions and Material Properties

The trial pitting carried out in February 2011 has confirmed that the geology of the site is in general agreement with that shown on the BGS mapping and report.

The ground investigation data shows that the ground conditions vary considerably throughout this small site. Although initially appearing to be varying depths of sands and gravels over bedrock detailed analysis of the trial pits logs and laboratory test results has found subtle variations in the nature of the superficial deposits. The nature and location of each type of deposit agrees with the geology anticipated in Section 3. Thicker deposits of a granular material with a high fines content, assumed to be Glacial Till, are found to the south of the site, coinciding with the proximity to the Berriedale Water and a possible pre-glacial channel. Further north on the higher ground where bedrock is at or near surface the granular material has a lower fines content and is more red and gravelly in nature, appearing more like a weathered rock with remnants of till.

The ground conditions across the site are therefore sub-divided as follows:

- Topsoil
- Made Ground
- Granular deposit with high fines content - Glacial Till
- Granular deposits with low fines content - Weathered Rock
- Bedrock

6.1 Topsoil

Topsoil was found across the route to depth of between 0.2m bgl and 0.5m bgl. The nature of the topsoil varied across the route depending on the nature of the land use. In the pasture land Ch 180m to Ch 350m the topsoil was dry and much like a slightly organic clayey sand. From Ch 0m to Ch 150m, where the land was un-kept and covered with bracken, the topsoil seemed damper with a greater organic content comprising root mass and decaying plant matter.

6.2 Made Ground

TP 16 was excavated behind the existing mass concrete retaining wall in front of the cemetery. Backfill to the wall was expected to be evident in the excavation behind the wall. Although there was no evidence of man-made items in the soil in TP16 there was a strong hydrocarbon odour in a band of damp grey sand from 1.1m to 2.6m bgl. It is possible that the hydrocarbons are dissolved in the groundwater and that the material is entirely natural. Until the nature and source of the contamination is confirmed by further investigation the possibility that the grey sand is backfill to the wall and was contaminated during construction works should be considered. The Preliminary Geo-Environmental Assessment (Section 8 of this report) discusses this in detail.

Possible made ground up to 1m deep was also encountered in TP 15 at the base of the retaining wall immediately south of the hairpin bend, although again the trial pit record makes no mention of there being any man-made items in the soil.

6.3 Granular soil with high fines content – Glacial Till

Superficial deposits consisting of granular soils with a high fines content were found to depths of 4m bgl in the southern part of the site, from Ch 0 to Ch 150m. TP 11 to TP16 inclusive were excavated along this part of the re-alignment. The superficial deposits encountered in the trial pits are described as gravelly silty clayey SAND, sandy silty clayey GRAVEL.

The appearance of the material in-situ was mainly a dense fine sand and silt matrix containing occasional to frequent gravels.

At depths the material colour is described as a dark grey brown but closer to the ground surface the colour has weathered to a light grey orange brown.

Laboratory test data for the Glacial Till is summarised in Table 6.1 below.

Particle size distribution tests found that the percentage of material of silt and clay sizes in these deposits ranges from 29% to 34%. Although three out of eight tests found the materials to be non-plastic, the remaining five tests recorded Plasticity Index ranging from 5% to 16%. The PI results for the material plot above and below the A-line on a plasticity chart (BS5930) and towards the boundary of the low and intermediate plasticity bands. As such the till is classified as a sand/gravel with fines content of low to intermediate plasticity: SGCL/SGCI.

The fines content of the material and its matrix-like in-situ appearance corresponds to that of the diamicton Glacial Till described by the BGS mapping and reports.

One optimum moisture content test was undertaken on the till, recording an optimum moisture content of 6.9% and a corresponding maximum dry density of 2.2Mg/m3. Natural moisture contents of the material ranged from 10% to 27%, with the mean being 14.6%.

Two California Bearing Ratio tests on soaked samples recorded very low CBR values of 0.94% to 1.7%. Moisture Condition Value testing similarly recorded a low MCV value of 2.8.

In a small shear box test the angle of shearing resistance of the sample of till was found to be 38°.

6.4 Granular soil with low fines content – Weathered Rock

Between Ch 150m to Ch 350m the ground conditions were investigated by trial pits TP 01 to 10 inclusive. The superficial deposits encountered are described as very sandy silty clayey GRAVEL, very gravelly silty clayey SAND and silty clayey SAND/GRAVEL. In TP 05 and TP08 angular flaggy fragments of the underlying bedrock were recorded at the base of the excavations. In terms of visual appearance the material appears to be coarser than the superficial deposits encountered to the south between Ch 0 – 150m with a larger proportion of more angular red sandstone gravels. The colour is recorded as more red brown and less grey. Minimal superficial deposits were present between Ch 210m to Ch 280m where rockhead was encountered within 0.5m of the ground surface (refer to Section 6.5 for full details of the rock characteristics).

Laboratory test data for the Weathered Rock is summarised in Table 6.1 below.

Particle Size Distribution tests found that the percentage of material of silt and clay sizes ranges from 12% to 25%. Six out of eight tests found the materials to be non-plastic, the remaining two tests recorded Plasticity Indexes of 4% and 5%, on samples which contained 24% silt and clay size material. The material plots below the A-line on a plasticity chart (BS5930) so is classified as a sand/gravel with low plasticity silt content: SGML.

Given the slightly coarser nature of the material and the presence of sandstone gravels between Ch 150m and Ch 280m, the superficial deposits are considered to be mainly weathered rock with perhaps remnants of till, as suggested by the fines content.

Three optimum moisture content tests were undertaken on the weathered rock, recording an optimum moisture content of between 7.1% and 8.5% and a corresponding maximum dry density of 2.14 to 2.33Mg/m3. Natural moisture contents of the material ranged from 8.4% to 15%, with the mean being 11%.

California Bearing Ratio testing on soaked and un-soaked samples recorded CBR values of 0.6% (un-soaked) to 18% (soaked). Moisture Condition Value testing recorded MCV values of 8.4 to 17.4 with a MCV calibration line showing a sensitivity of 3% (MCV per % mc). In the small shear box test the angle of shearing resistance of the sample of till was found to be 29°.

Table 6.1 Summary of properties of superficial deposits

	TP 1 to 3 inclusive (see note 1)		TP 7 to 10 inclusive Weathered Rock		TP 11 to 16 inclusive Glacial Till	
Property	**Min-Max**	**Mean**	**Min-Max**	**Mean**	**Min-Max**	**Mean**
PSD (passing 63um sieve) (%)	14 – 26	21.67	12 – 24	18	29 – 34	30.5
Natural Moisture Content (%)	9.7 – 14	11.43	8.4 – 15	10.8	10 – 27	14.63
Liquid Limit (%)	18 – 20	19	17 – 22	20.2	13 – 34	21.63
Plastic Limit (%)	All tests non plastic	-	3/5 tests non-plastic 2 plastic tests: 12 -16	All tests: 5.6 2 plastic tests: 14	3/8 tests non-plastic 5 plastic tests: 12–15	All tests: 8.25 5 plastic tests: 13.2
Plasticity Index (%)	All tests non plastic	-	3/5 tests non-plastic 2 plastic tests: 4 – 5	All tests: 1.8 2 plastic tests: 4.5	3/8 tests non-plastic 5 plastic tests: 5 – 16	All tests: 5.75 5 plastic tests: 9.2

	TP 1 to 3 inclusive (see note 1)		TP 7 to 10 inclusive Weathered Rock		TP 11 to 16 inclusive Glacial Till	
Property	**Min-Max**	**Mean**	**Min-Max**	**Mean**	**Min-Max**	**Mean**
Optimum Moisture Content (%)	7.1 – 8.2		8.5		6.9	
Maximum Dry Density (Mg/m3)	2.14 – 2.33		2.16		2.2	
CBR (%)	13 - 18		0.6 – 5.77		0.94 – 1.7	
MCV	12.7 (int)		8.4 – 10.6		2.8	
Angle of Shearing Resistance (Φ')	No test undertaken		29		38	
Sulphate Class	Refer to Section 7 for details of aggressivity test results					

Notes:

1) It is not possible (due to limited data) to determine reliably the origin of the superficial material at these locations but they are possibly glacial meltwater in origin.

Appendix 2 contains plots of the following laboratory testing results:

- Plasticity Chart
- MCV v Moisture content relationship
- Particle Size Distribution

6.5 Bedrock – Berriedale Sandstone/Berriedale Flagstones

Between Ch 200m and Ch 300m trial pits TP03 to TP08 inclusive encountered bedrock at depths varying from 0.5m bgl to 1.6m bgl. Bedrock was found to be at its shallowest between Ch 210m to Ch 280m. Close by, at a high point in the topography of the site, the rock could be seen outcropping at ground level.

The bedrock at the base of the trial pits was recorded as a fine grained brownish red flaggy siltstone or sandstone which was recovered as gravel to boulder sizes.

The machine used for the trial pitting was unable to excavate into the rock to allow inspection of its in-situ characteristics or to obtain samples. As such inspections of three exposed rock faces in the vicinity of the site were undertaken; firstly two faces of the shoreline cliffs below Ch 50m to Ch 150m of the re-alignment option then a rock cut on the northbound A9 immediately south of the hairpin bend. Summary reports from the rock face inspections are provided in Section 6.5.1.

Samples of rock were obtained by gathering loose rocks from the rock faces. Rock testing was undertaken on samples obtained both from the trial pits and from the rock faces. The test results are summarised in Table 6.2 below.

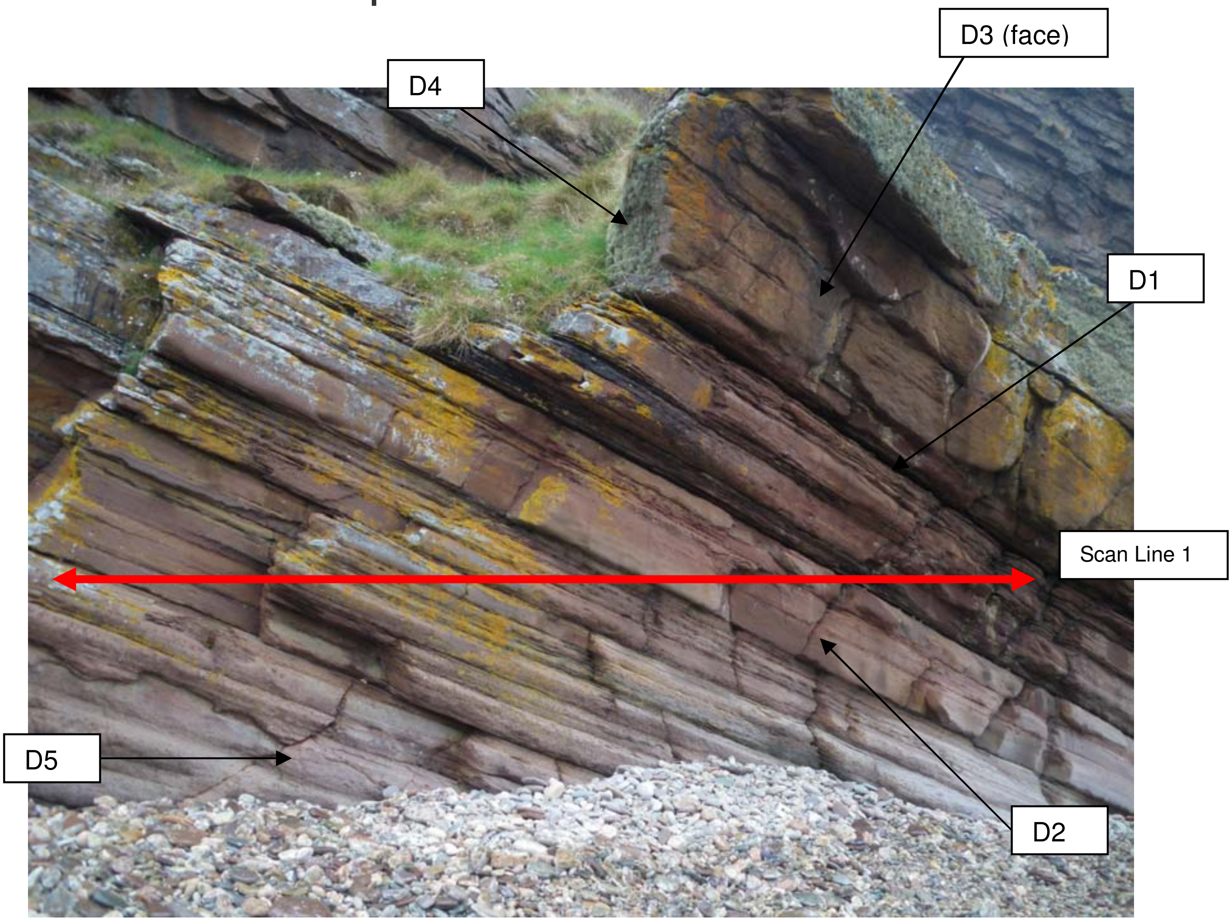
Point Load lump tests found the rock to have an Is (50) value of between 0.06MPa and 7.37MPa, although the range of average values is much narrower, being between 1.3MPa to 4.86MPa. As there was no rock core recovered from the site, no uniaxial compression tests could be undertaken and it is not possible to derive a site specific correlation between the point load index results and a uniaxial compressive strength of the rock.

Los Angeles coefficient values results of 22 to 26 were recorded over four tests on samples obtained from the rock faces and samples recovered from the trial pits. Magnesium sulphate soundness values of 4% to 7% were recorded, again over four tests on samples recovered from the rock faces and trial pits. Two water absorption tests recorded results of 1.1% and 1.3%, again in one sample from a rock face and the other from a trial pit.

Table 6.2 Summary of Bedrock properties

Sample Location	Is (50), MPa	Average of set of five Is (50) tests, MPa	Los Angeles Value	Magnesium Sulphate Soundness Value (%)	Water Absorption (%)
TP04	0.16 to 5.98	3.03	26	7	No data
TP05	0.06 to 3.33	1.32			1.3
TP08	2.19 to 5.41	3.84	22	7	
Shore 1	1.61 to 5.00	3.13			
Shore 2	1.24 to 7.37	4.86	22	4	
Shore 3	2.44 to 5.73	3.82			
Shore 4	3.38 to 4.62	3.96			
Shore 5	1.18 to 5.78	3.49			
Road 1					
Road 2					
Road 3					
Road 4			24	6	1.1

6.5.1 Rock face inspections



Scan Line 1

Location: Shoreline below Berriedale Braes.

Orientation: Facing near south (170°)

Rock Type: Medium and occasionally thickly bedded light brownish red fine grained Siltstone.

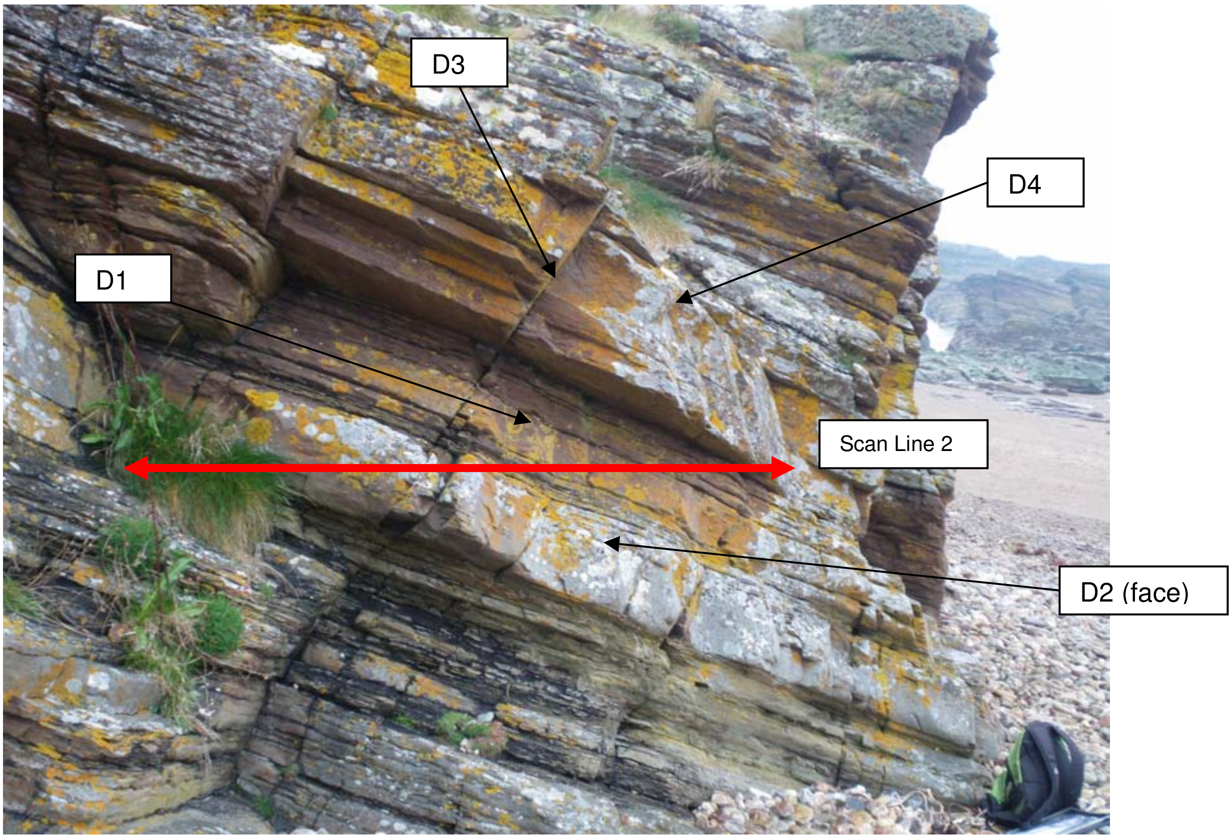
There are five discontinuities: D1, D2 and D3 are an orthogonal arrangement, creating medium and large tabular blocks. D4 and D5 are a conjugate set creating a prismatic block shape.

D1 is the bedding. Bedding spacing is 200mm to 600mm (occasionally >600mm but <1m). Bedding surfaces are rough planar, tight to very moderately wide in aperture and are either clean or in-filled with disintegrated rock. Along many bedding surfaces a 30mm – 50mm zone of weathered fragmented rock is present. Bedding dip (°) and dip direction (with compass north being 0°) ranges from 12/070 to 15/070. The bedding is the dominant and most persistent discontinuity.

D2 and D3 are smooth clean planar moderately wide near vertical joints, almost perpendicular to the bedding plane. D2 dips east north east and D3, which creates the face of the blocks, has a northerly dip direction. These are widely spaced (0.6m to 2m).

D4 and D5 are a conjugate joint set.

The rock is dry and seepage is not visible at any surface.



Scan Line 2

Location: Shoreline below Berriedale Braes.

Orientation: Facing near west (260°), perpendicular to scan line 1.

Rock Type: The rock is thin to medium bedded light brownish red fine grained Siltstone.

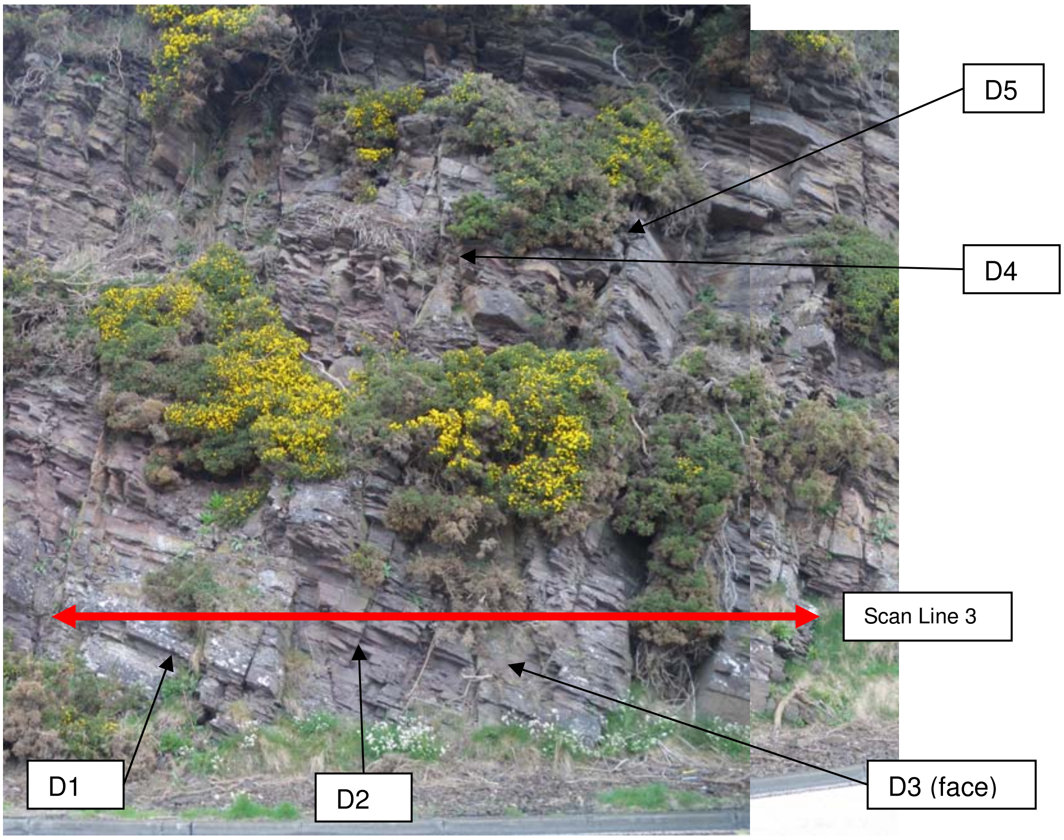
There are four discontinuities: D1 is the bedding, D2 and D3 are an orthogonal arrangement, creating medium and large tabular blocks, and D4.

D1 is the bedding. The bedding spacing is 60mm to 0.6m with moderately wide to wide rough planar discontinuity apertures containing some surface staining and disintegrated rock. The bedding is orientated at 22/120 to 25/130. The bedding is the dominant and most persistent discontinuity.

D3 on this face is a medium to wide spaced smooth planar joint with a dip of 60° just west of north and is tight to moderately wide in-filled with disintegrated rock when moderately wide and clean or surface staining when tight. D3 forms the face of the rock blocks on Scan line 1. D2 on scan line 1 forms the block faces, D2, on this scan line.

A third wide spaced joint, D4, is recorded with a dip of 70° to the south west with partly open to moderately wide clean smooth planar surfaces.

The rock is dry and seepage is not visible at any surface.



Scan Line 3

Location: Northbound verge of A9 south of Berriedale hairpin bend.

Orientation: Facing south west (220°).

Rock Type: Medium bedded light brownish red fine grained Siltstone.

There are five discontinuities: D1 is the bedding, D2 and 3 are an orthogonal arrangement forming medium tabular blocks, D4 and 5 are a conjugate set.

D1 is the bedding. Bedding spacing is 0.2m with dip of 15° to south-southeast separated by a rough planar tight to wide aperture either clean or in-filled with disintegrated rock. Around many bedding planes there is a 30mm zone of disintegrated rock. The bedding is the dominant and most persistent discontinuity.

D2 and D4 are both generally medium to widely spaced but with one instance of very close spacing. D4 lies at 70/140 to 80/160 and the D2 at 70/320 to 80/340. Their aperture ranges from open to wide and are in-filled with disintegrated rock of non-cohesive soils and roots from the overlying soil and gorse cover. When the two joints are closely spaced the rock between is fragmented into small to very small blocks. D5 has similar dip and direction to D2 but is more persistent and runs the full height of the rock face. D4 is also very persistent and runs the full height of the rock face. D3 forms the faces of orthogonal blocks.

On this face 40mm diameter drill holes were noted at approx 1m intervals.

The rock is dry and seepage is not visible at any surface.

7 Geotechnical Engineering Considerations

7.1 Re-Alignment Option

The geotechnical considerations for the re-alignment option are covered in Section 7.1 below. Geotechnical considerations for the local widening option are discussed in Section 7.2. Particular geo-environmental issues are covered in Section 8.

7.1.1 Cutting Stability

The cutting for the re-alignment option will be predominantly in rock. Cut slopes in superficial deposits are likely to be formed in only two locations; as the rockhead level deepens and till deposits increase in thickness at the south end of the cutting, and in the sand and gravel weathered rock above the bedrock.

As it was a feasibility stage ground investigation, the site works were undertaken within a limited budget and comprised only trial pits. An assessment of the cutting stability in superficial deposits is therefore made using the visual observations recorded during trial pitting, limited laboratory test data, empirical correlations, and comparison of proposed slope profiles with existing slope profiles in the area. The rock cutting slopes are assessed using data from the inspection of two exposed rock faces in the vicinity of the site.

A cutting of up to 9m will be formed between Ch120m and Ch 300m. The deepest part of the cut coincides with the location of shallowest bedrock, so the majority of the 9m cut will be a rock cutting. Towards the south of the cutting the maximum cut depth in superficial deposits could be between 4m to 5m depending on the rock level (not encountered in the relevant trial pits) between Ch 120m and Ch 180m.

Cutting in Glacial Till and Weathered Rock

Laboratory testing has found the weathered rock and till to have angles of shearing resistance of 29° and 38°. Grading data suggests that the material will behave as a fine sand/coarse silt with a high sand and gravel content and an estimated critical state angle of shearing resistance of 34° is expected (from BS8002:1994, Clause 2.2.4). Existing natural slopes in the till are standing at angles of 35° or steeper in the area (although no analysis has been undertaken to assess their current Factor of Safety). As such it is considered that 1v:2h slopes can be formed in the Weathered Rock and Glacial Till and should will have an acceptable FoS throughout their Design life. Drainage of the cut slopes will be vital to ensure stability. The nature of the slope drainage measures is described fully in Section 7.1.3.

<u>Cutting in Rock</u>

During the three rock slope inspections dip and dip direction data were recorded for input to DIPS software: a package that plots stereonets and facilitates assessment of the potential for sliding, toppling and wedge failure. At this stage the data collected is sufficient only for a preliminary assessment. The preliminary DIPS analysis was undertaken using the following geometric model:

- 2v:1h cut slopes in the rock
- Rock cut from Ch 210m to Ch 280m
- Southbound slope inclination of 63.5° from horizontal and dip direction of 212°
- Northbound slope inclination of 63.5° and dip direction of 032°
- Rock surfaces are planar and smooth to rough so have a friction angle of 30°

The preliminary DIPS analysis found the following:

- On both the northbound and southbound slopes there is a low risk of toppling failure, with no poles plotting in the toppling region of the stereonet.
- On both the northbound and southbound slopes there is a low risk of planar sliding, with only one pole (from a joint) plotting in the zone of planar sliding on the stereonet. The potential for sliding along the bedding planes would increase on both the northbound and southbound slopes if the angle of friction along the joints was less than assumed.
- There is a medium risk of wedge failure with two intersections plotting in the wedge sliding zone on the stereonets, one on the northbound slope and one on the southbound slope. The potential for wedge failure, especially on the southbound slope would increase if the angle of friction was less than assumed.

Further considerations about rock cut stability can be drawn from observations of the exposed rock faces.

- The more weathered rock at the top of the cutting is very fragmented and small to medium blocks look ready to fall (see photo 7.1).

Photo 7.1 Weathered rock and loose rock blocks on roadside rock cut

- Evidence of small scale rock falls as lower blocks fall off the face leaving overlying blocks unstable and at risk of failure.
- Minor wedge failures and are apparent on the roadside rock cut face, with occasional small to medium sized prismatic blocks present in the verge.
- The gorse on the rock face appears to be increasing the potential for failures as the roots force the joints further open.
- Blast damage may be the cause of some rock shattering, and this should be considered at detailed design stage.
- The rock faces are standing at near vertical inclinations but the face alongside the A9 falls slightly back away from the road whereas the shoreline cliffs have a slight overhang.

Although the risks of the three main failure mechanisms were found to be low, this should be confirmed at detailed design stage by further detailed inspection of exposed rock faces in the area in conjunction with assessment of core logs and down hole geophysical results at the rock cut location. The more detailed work will also confirm any requirements for rock slope treatments (rock netting/bolting etc) and /or rock ditches. Land take and geometry of the re-alignment will be affected by the presence of rock trap ditches.

7.1.2 Embankment Stability and Strengthened Earthworks

The two areas of fill on the site lie at the northern and southern tie-ins of the re-alignment with the existing A9. In both cases the topography is steeply sloping sidelong ground and it is not possible to form a 1v:2h slope in the land available. As such a strengthened earthwork (reinforced fill slope) or structural solution is required. The slopes will be up to 10m high at the southern tie in, a substantial height. Side slopes of the reinforced earth fill may have to be in the order of 1v:1h to fit within the land available. However, a composite slope with a small 1v:2h upper section and steeper reinforced fill lower section or retaining structure may be more practical to accommodate services, drains, and safety fencing in the verge. The land take shown on Figure 2 is based on an average 1v:1h slope.

Glacial Till underlies the site at the southern tie-in. Rock was not encountered within 4m of the existing ground level. Laboratory shear box test data found the angle of shearing resistance of the Till to be 38°. Preliminary calculation has found that the bearing pressures anticipated from the earth fill, which could be up to 10m high at Ch 100m, are unlikely to exceed the net safe bearing capacity of the material. As such it is considered likely that the Till would be an acceptable bearing strata for a reinforced earthfill structure.

The reinforced earthfill would be designed to satisfy all internal stability criteria, taking into account imposed loads. Therefore the main geotechnical issue relates more to the global and external stability of a reinforced earthfill structure or retaining wall on the side-long cliff-side slopes as well as the internal stability or bearing capacity. Insufficient data is currently available about the stratigraphy of the underlying deposits, rockhead level and groundwater profile to allow detailed analysis. Further ground investigation is required to establish these parameters and inform an accurate ground model for use in analysis and detailed design.

An alternative to a steep reinforced earthfill would be to provide a 'hard' structural solution. Again, the global stability would be a concern for any structures with spread footing bearing onto the glacial tills. If future ground investigation work encountered shallow rockhead perhaps a bored piled wall with a rock socket could be considered as an alternative, although it would be a greater cost than reinforced earth, less sustainable and with potentially more constructability challenges.

At the northern tie-in limited ground investigation data is available. It is anticipated that underlying ground conditions would be similar to those at the southern tie-in. Given that the fill at the north tie-in would also be constructed onto side-long ground the same concerns about global stability arise. Further ground investigation would be essential to inform a detailed design.

Settlement

At both tie-ins settlement and consolidation of the underlying material is likely to occur as a result of the increased loading from a new reinforced earth embankment.

The Glacial Till underlying the new fill has up to 30% fines, thus it may not dissipate excess pore pressures rapidly, so settlements may not be entirely complete by the end of the construction works. To prevent differential settlement between the new fill and the existing road a short pause period may be appropriate before constructing the road pavement and drainage. This should be considered in more detail when planning the detailed investigation for the scheme. The fill should be monitored to determine when settlements are reduced to an acceptable level. If the construction programme did not allow for a pause period alternatives such as staged construction or ground improvement could be considered.

7.1.3 Drainage

Drainage will be required towards the south end of the cutting, Ch 140m to Ch 200m. TP10, located on the southbound side of the proposed cutting, encountered seepages from 1m bgl. Although no water was encountered in TP09, on the northbound side of the proposed cutting, it would be prudent to make provision for slope drainage on both the southbound and northbound sides of the cutting, especially due to the fines content of the soils and their sensitivity to increased moisture content. Piezometers installed in future ground investigation works would establish groundwater levels and confirm the need for drainage.

All trial pits between Ch 200m to Ch 280m, where rockhead is 0.5m bgl or so, were dry with no seepage recorded at the rock/soil interface. However, due to the topography of the area crest drains would be required along the top of the southbound slope, between Ch150m to Ch 300m, to intercept surface water as it flows downhill over the grassy field towards the coast. These crest drains should be installed to sufficient depths to intercept sub-surface flows at rockhead or in weathered rock zones.

No information is available about groundwater within the rock mass, although the hydrogeological map notes that, if present, groundwater would be mainly within fissures and discontinuities of the rock. Rotary boreholes should be advanced into the rock to determine groundwater levels and flow and establish whether drainage measures in the rock cut are required.

7.1.4 Re-Use of Site Won Fill

The majority of the excavation to form the cutting will be in rock with only the northern and southern ends of the cut yielding any 'as-dug' soil materials.

Weathered Rock and Glacial Till

PSD testing shows that the weathered rock to be excavated is a mix of Class 1A and Class 2C fill. Some of the tests that classify within the 2C grading are marginal (15% and 18% passing 63um sieve) and it is possible that a mixed stockpile could be predominantly a Class 1A fill material. Of the Class 2C results, all are low plasticity.

MCV testing shows that the material is very sensitive to water with a 1% change in moisture content causing change in MCV value of 3.

The glacial till has a greater fines content, up to 34% silt and clay sizes. For re-use as fill the till classifies as a Class 2A/B or a Class 2C on the basis of PSD tests. The material has low to intermediate plasticity.

Both materials at their mean natural moisture contents of 10.8% and 14.6% are wet of the optimum moisture contents of 8.5% and 6.9% required to achieve maximum dry density, 2.16Mg/m^3 and 2.2Mg/m^3 during compaction. Therefore the till material would require processing to reduce moisture content to render it acceptable as general fill.

Due to their substantial fines content the as-dug materials suitability for use as Class 2 fill would be controlled by MCV testing. From relationship testing the acceptable MCV limits have values of between 8 and 17 to ensure that the moisture content of the fill is such that 95% maximum dry density could be achieved in compaction (refer to MCV v moisture content plot in Appendix 2).

None of the superficial deposits tested complied with the grading requirements for Class 6I or Class 6J, fill to reinforced earth structures. Unless the rock excavated from the cutting was processed down to the Class 6I or Class 6J grading, imported fill would be required to form the reinforced earthfill embankments at the north and south of the site.

Rock

Testing undertaken on the rock samples obtained from the base of trial pits and from the two exposed rock faces has found that the rock is likely to be suitable for re-use in the scheme as general fill, capping or sub-base once it is crushed and screened to the required grading.

The Los Angeles coefficients of 22 to 26 are indicative of a rock with high resistance to fragmentation. Class 6F5 (capping) and Type 1 sub-base require LAV <50 and <30 respectively so the site-won rock, if crushed to the correct grading, could be suitable for either as well as for general fill.

The Magnesium Sulfate soundness values of 4% to 7% indicate a rock with low percentage loss when subject to weathering. Again the rock could be suitable for general fill as well as Type 1 which requires MS < 35%.

Water absorption is an indicator of the frost susceptibility of a rock. The Berriedale rocks had a water absorption of 1.1% to 1.3% suggesting low frost susceptibility and the suitability of the rocks for use in the upper layers of the earthworks as capping or sub-base material.

Point load index tests found the rock samples to range from weak to very strong, but on average the rock was moderately strong.

7.1.5 Rock Excavatability

Excavatability of a rock cutting in the Berriedale Flagstones underlying the site is assessed using guidance provided in Figure 5.1 of 'Rock Engineering Guide to Good Practise, Road rock slope excavation' (TRL report PR/ISS/16/00). A point load index of 0.06 to 7.37 with an average value of 3.43 and a fracture spacing index of 0.3 – 1.5m are adopted for this preliminary assessment.

For this range of data Figure 5.1 of TRL PS/ISS/16/00 shows that hard to extremely hard ripping and blasting are likely to be the methods required to excavate the rock mass.

It is possible that the assumed values may be on the low side as the data is obtained from exposed rock faces and samples of rock that have either fallen from an existing cut face or are at the base of a trial pit, so therefore weathered. If this was the case the rock mass may be 'stronger' than estimated and blasting or other methods of fragmentation may be required to enable excavation of the rock.

It is worth noting that drill holes for blasting can be seen in the rock cut on the northbound A9 just south of the hairpin bend, 40mm diameter at approx 1m spacing. If records of the blasting works were available this could inform future works.

Detailed fracture spacing and UCS data should be obtained during a detailed ground investigation to inform excavatability assessments.

7.1.6 Pavement Design

A limited proportion of the re-alignment will be at-grade. Generally the route will either be on fill or in a cutting with the formation likely to be in rock. Testing undertaken on the till and weathered rock likely to be encountered at formation level in at-grade sections found a wide range of CBRs, from 0.6% to 18%.

More testing would be required to complete an economic pavement design.

From past experience of working with the fine sensitive soils it is anticipated that a capping layer would be required. In addition the subgrade would be easily damaged if trafficked, so minimal trafficking or a protection layer would be recommended during the construction phase.

Where the subgrade level is in rock and CBR values exceed 15% a minimum 200mm of sub-base or capping is required. The need for a free-draining layer beneath the pavement will be established once it is known if there is groundwater within the discontinuities in the rock mass and what drainage strategy is proposed.

At the north and south cut/fill transitions (both along and across the road) a transition zone would be required where the subgrade changes from sand/gravel superficial deposits to rock or to compacted fill.

7.2 Local Widening Option

The area between the cemetery and the retaining wall is underlain by glacial till with rock believed to be at shallow depth, although rockhead was not encountered in the TP16 excavated to 4m bgl.

To improve the road geometry at the bend by locally widening the road would mean demolition of the existing wall (see photo 7.2) and construction of a new wall or reinforced steep slope further north towards the cemetery. Simply trimming the existing slope to a steeper angle would not be possible as the angle of shearing resistance of between 29° and 38° limits a stable slope profile to 1v:2h, which would not provide sufficient space for widening at road level.

Photo 7.2 Cemetery and retaining wall at the 'Local Widening' location

Existing retaining wall to be demolished and either re-built further back towards cemetery or replaced by a steep slope to allow widening of the carriageway.

Further ground investigation is required to obtain details of rockhead profile and the properties of the backfill to the retaining wall. A detailed topographical survey from the A9 to the cemetery and the immediate vicinity would also be essential as there is currently no topographic information for this area.

From the data available it is known that rock lies below 4m bgl and the overlying superficial deposits are damp sands and glacial till. It is reasonable to assume that the superficial deposits behind the retaining wall would not stand unsupported whilst a new wall was being built. Thus temporary works would be required for any reconstruction of the wall. To minimise construction works which would inevitably disrupt traffic flow on the road, options are considered which use only one stage of construction:

- Bored piled wall installed from a flat bench formed in the slope immediately behind the retaining wall with a temporary slope (supported with temporary works if necessary) up to the cemetery. The piles would be installed with the existing wall still in place. Once the piled wall had gained strength the existing wall and its backfill would be removed leaving the piled wall supporting the cemetery. Tie-back anchors could be installed to minimise the length of the piles, thereby reducing the size of construction plant and facilitating the work in the limited site area.

- Soil nailed solution. Soil nails would be installed in stages in top down construction and a slope profile of 60° to 70° formed as nailing progressed. If the toe of the slope had to be steepened further to achieve the widened road the lower soil nails could act as temporary nails to hold the slope in place whilst a toe wall was being constructed. The road may be able to stay open during soil nail installation if safety measures (eg. safety barriers/debris nets) were installed along the existing wall to minimise risk to road users from construction works. This soil nailed slope option is illustrated in Figure 4 included in Appendix 3.

Elevated levels of hydrocarbons were recorded in the sands behind the existing retaining wall. Further investigation is required to establish if this was an isolated or prevailing condition. Excavation of the material from behind the wall would be more costly if the contamination was common to the whole area and once excavated the material would not be suitable for re-use so would incur expensive off-site disposal charges for Class U1B (unacceptable, contaminated but non hazardous waste) material. These aspects are discussed more fully in Section 8 of this report.

The aggressivity class for the soils encountered at the local widening option is also discussed in Section 8.2.3.

7.3 Summary of Geotechnical Considerations

The purpose of this 2010/2011 work was to ascertain whether the ground conditions would be such that either the re-alignment option or the local widening option could be feasibly taken forward to the next stage of design. The 2011 ground investigation works and the various site inspections have found that the ground conditions are reasonably favourable for both options.

In the re-alignment option the deepest cutting is in rock so there would be limited slope stability issues in design and minimal land-take required for the cutting. More details should be gained about the in-situ rock mass to determine the rock slope stability and rock slope treatment.

The main concern arising from the ground investigation is the global stability of the reinforced earth embankments (or any type of fill or structure) on the sidelong cliff-side glacial till slopes at the northern and southern tie-ins with the existing A9. Greater detail about the in-situ nature of the glacial till, stratigraphy and groundwater at each tie-in location would be required for detailed design.

The feasibility of the local widening option is not dictated so much by the ground conditions as by the nature of the site. If local widening was favoured then the design would partly be driven by the constructability of the solutions, as well as consideration of the ground conditions. The sandy nature of the soils encountered suggests that any solution would not be able to use un-supported steep slopes, either in a temporary or permanent condition.

8 Preliminary Geo-Environmental Assessment

8.1 Contamination Conditions Encountered

8.1.1 Visual and Olfactory Assessment

Visual and olfactory notes made during the ground investigation identified the presence of a strong hydrocarbon-type odour throughout the grey clayey gravelly sand strata (1.1-2.6mbgl) within TP16. No discolouration of the ground and no Made Ground was identified either at or above this ground level. In addition, no die-back of vegetation was observed at or within the vicinity of this locality.

Soil samples collected from this stratum were observed to swell with gas upon placing the sample within a sealed bulk bag suggesting that the contamination was of a gaseous and potentially volatile nature. Free product was not encountered at this location.

This stratum was recorded as damp throughout, existing below perched water seepage.

The source of this contamination is as yet unknown but may be associated with the adjacent graveyard, located directly up-hydraulic flow of the sample location.

No other potential contamination was observed within soil or groundwater seepages present in trial pits although possible Made Ground was identified within TP15 below topsoil at between 0.35 to 1mbgl owing to its proximity to the retaining wall.

8.1.2 Sampling for Contamination Purposes

A total of four soil samples were obtained from shallow soils and analysed during the ground investigation. One sample of soils was from both trial pits TP04 and TP15. Two samples were obtained at different depths from TP16; one from the gravelly sand (at 0.5m bgl) above the level of perched groundwater seepage and the second from the damp gravelly sand below.

8.2 Preliminary Quantitative Risk Assessment

8.2.1 Contaminant Risks to Human Health

As a preliminary contamination assessment, all four soil samples were compared to Tier 1 guideline values available. These guidelines have been generated in-house using principles of the Contaminated Land Exposure Assessment (CLEA) framework as provided by the Environment Agency using their published CLEA V1.06 software model. Toxicological and physiological parameters used to generate in-house generic assessment criteria (SWGACs) have been derived from a variety of sources including those presented by the Environment Agency within CLEA, Land Quality Management (LQM), The Chartered Institute of Environmental Health (CIEH), CL:AIRE (Contaminated Land Applications in Real Environments) and USEPA. SWGACs have been generated for a variety of end uses and for this development, the most applicable end use for human end users (including maintenance workers and construction workers) is considered to be those SW GACs available for a commercial end use. Contamination results are presented in the following table alongside Tier 1 SWGACs.

Table 7.1 Contamination Test Results

Determinand		SW-GAC mg/kg^	Results Range (mg/kg)	Significant?	Comments
Arsenic	4	635	3-6	N	
Boron (water soluble)	4	-	<1	-	
Cadmium	4	230	<1	N	
Chromium (total)	4	34 (as VI)	13-21	N	
Copper	4	71,700	6-10	N	
Lead	4	5,950	16-40	N	
Mercury	4	3,600 (inorganic)	<1	N	
Nickel	4	1,780	9-15	N	
Selenium	4	13,000	<3	N	
Sulphate as SO_4 (total)	4	-	0.02-0.05%	-	
Sulphate as SO_4 (2:1 water extract)	1	-	<10mg/l	-	
Total sulphur (%)	4	-	<0.01-0.02	-	
Vanadium	4	3,164	12-22	N	
Zinc	4	665,000	26-42	N	
Cyanide (total)	4	193 (free cyanide)	<1	N	
Phenols (total monohydric)	4	31,000	<1	N	
Sulphide	4	-	<10	-	
Asbestos	4	Fibres detected/not detected	No asbestos detected	N	
pH	4	-	5.3-6.4	-	
Soil Organic Matter	1	-	0.5%		
Toluene extractable matter	4	-	<500	-	
Total petroleum hydrocarbons	1	-	1,700	-	TP16 @ 1.3m only
TPH (C5-C6 Aliphatic)	1	3,385 (304) mg/kg	<50 ug/kg (<0.05mg/kg)	N	
TPH (C6-C8 Aliphatic)	1	8,250 (144)	5,600 ug/kg (5.6mg/kg)	N	
TPH (C8-C10 Aliphatic)	1	2,126 (78)	47,000 (47mg/kg)	N	
TPH (C10-C12 Aliphatic)	1	10,260 (48)	120 mg/kg	**Y (SOIL SATURATION LIMIT ONLY)**	
TPH (C12-C16 Aliphatic)	1	60,790 (24)	590 mg/kg	**Y (SOIL SATURATION**	

				LIMIT ONLY)	
TPH (C16-C21 Aliphatic)	1	>1,000,000 (8.5)	500 mg/kg	Y (SOIL SATURATION LIMIT ONLY)	

Determinand		SW-GAC mg/kg^	Results Range (mg/kg)	Significant?	Comments
TPH (C21-C35 Aliphatic)	1	>1,000,000 (8.5)	86 mg/kg	Y (SOIL SATURATION LIMIT ONLY)	
TPH (C35-C40 Aliphatic)	1		<10 Mg/kg	Y (SOIL SATURATION LIMIT ONLY)	TP16 @ 1.3m only
TPH (C6-C7 Aromatic)	1	27,650 (1,220)	<50 (<0.05mg/kg)	N	
TPH (C7-C8 Aromatic)	1	59,000 (869)	<50 (<0.05mg/kg)	N	
TPH (C8-C10 Aromatic)	1	3,665 (613)	22,000 (22mg/kg)	N	
TPH (C10-C12 Aromatic)	1	16,950 (364)	<10mg/kg	N	
TPH C12-C16 Aromatic)	1	36,290 (169)	25mg/kg	N	
TPH C16-C21 Aromatic	1	28,200	36mg/kg	N	
TPH (C21-C35 Aromatic)	1	28,400	<10mg/kg	N	
TPH (C35-C40 Aromatic)	1		<10mg/kg	N	
BTEX					
Benzene		28	<5ug/kg (<0.005 mg/kg)	N	
Ethylbenzene		16,780 (518)	170 ug/kg (0.17 mg/kg)	N	
Toluene		59,000 (869)	<5ug/kg (<0.005 mg/kg)	N	
Xylene (m-, p-)		6,930 (478)	1,100 ug/kg (1.1mg/kg)	N	
Xylene (o-)		6,220 (576)	<5 ug/kg (<0.005 mg/kg)	N	
VOCs					
n-Propylbenzene		4,090 (402)	1,200 ug/kg (1.2 mg/kg)	N	
1,3,5 Trimethylbenzene		-	6,000 ug/kg (6.0 mg/kg)	-	
1,2,4 Trimethylbenzene		41.7	1,600 ug/kg (1.6 mg/kg)	N	
S-Butylbenzene		-	1,200 ug/kg (1.2 mg/kg)	-	
p-Isopropyltoluene		-	2,200 ug/kg (2.2 mg/kg)	-	

^ Appropriate for a commercial end use.
Soil saturation limit given in brackets

It was not possible to perform statistical analysis on the contamination results owing to the limited contamination data available for this preliminary ground investigation.

Concentrations of petroleum hydrocarbons were recorded below the soil saturation limit or SW GAC for commercial land use for the sample tested. However, concentrations of individual aliphatic hydrocarbon bands within both the diesel and mineral oil range (>C10-C35) were found to exceed the soil saturation limit derived in TP16 @ 1.3mbgl (the only sample tested). The soil saturation limit identifies the theoretical concentration of the contaminant, above which the contaminant has the potential to be present as free product. Although a strong hydrocarbon odour was encountered within the groundwater at the sampled depth, free product was not recorded within this particular borehole during the ground investigation. Therefore it is considered appropriate to assess the concentrations of these carbon bands against the higher human health risk assessment criteria whereby no exceedances are subsequently identified.

Small concentrations and traces of lighter end aromatic hydrocarbons (C8-C10) and volatile organic compounds were additionally encountered although none exceeded the tier 1 guidelines for human health.

Risks from the dissolution of asphyxiant ground gases (e.g. carbon dioxide, methane etc) within perched groundwater at this location are, however, still considered a potential risk to human health of future site users (particularly to construction workers and any maintenance workers who may enter manholes and other enclosed paces where ground gases may build up) despite the insignificant concentrations of lighter hydrocarbons and VOCs within the sample analysed.

8.2.2 Contaminant Risks to Controlled Waters

No groundwater or soil leachate samples were collected during the preliminary ground investigation. There appears to be the potential for contamination of perched groundwater within the vicinity of TP16, the source of which is unknown although may potentially be associated with the adjacent graveyard.

8.2.3 Contaminant Risks to Proposed Infrastructure

Sulphate analysis has been undertaken in accordance with BRE Special Digest (SD1: 2005), 'Concrete in Aggressive Ground', in order to classify the sulphate class of the ground. Three samples from the sandy gravelly clay encountered below perched groundwater seepages were scheduled for analysis in accordance with BRE Special Digest (SD1:2005), Concrete in Aggressive Ground'. A further three samples were scheduled for total sulphate, total sulphur and pH. Total sulphur concentrations were 0.01%. Water soluble sulphate was recorded at either <10mg/l and 10mg/l SO_4. pH was recorded between 5.3 and 6.4.

Based on the assumption that mobile groundwater is present, the preliminary assessment has derived the following classification:

- Proposed route widening option:
  - Design Sulphate Class DS-1
  - Aggressive Chemical Environment for Concrete Class AC-3 (as a worst case assessment)

-
- Proposed route realignment option:
  - Design Sulphate Class DS-1
  - Aggressive Chemical Environment for Concrete Class AC-2

8.2.4 Conceptual Site Model

Current legislation relating to contaminated land in the UK is contained within Part IIA of the Environmental Protection Act 1990 (as amended), which was inserted by Section 57 of the Environment Act 1995, and by Section 86 of the Water Act 2003.

The risk assessment process for the environmental contaminants is based on a source-pathway-receptor analysis. These terms can be defined as follows:

- Source: Hazardous substance that has the potential to cause adverse impacts;
- Pathway: Route whereby a hazardous substance may come into contact with the receptor: examples include ingestion of contaminated soil and leaching of contaminants from soil into watercourses;
- Receptor: Target that may be affected by contamination: examples include human occupants/users of site, water resources (surface waters or groundwater), or structures.

For a risk to be present, there must be a viable pollutant linkage; i.e. a mechanism whereby a source impacts on a sensitive receptor via a pathway.

Based on the potential contamination sources present and the preliminary ground investigation, the following table presents the potential Pollutant Linkages for both the Carriageway Widening and realignment Options.

Table 7.2 Pollutant Linkages

Option Affected	Contaminant Source		Pathway		Receptor	Comments
Option 1: Local Carriageway Widening	Hydrocarbon contaminants in perched groundwater generated from sources up-hydraulic gradient of TP16 – likely to be derived off site, (potentially associated with the graveyard/spill up hydraulic gradient of the site)	➧	Direct contact pathways (ingestion, inhalation, dermal contact) Migration, dissolution, diffusion (horizontal) and volatilisation	➧	Future Site Users including Construction Workers and maintenance workers.	Construction workers involved in the earthworks are considered to be at most risk of encountering contamination. Such risks can be mitigated by using personal protective equipment and through employing site health and safety controls. Maintenance workers are only considered to be at risk if in direct

Option Affected	Contaminant Source		Pathway		Receptor	Comments
						contact.
					Development Infrastructure	Risks to concrete in contact with aggressive contaminants within the ground can be mitigated through using the appropriate classification of concrete in line with the BRE Special Digest for Concrete.
					Surface Watercourses (Berriedale Water and associated Burn)	Contamination within groundwater intercepted by drains may need to be addressed to ensure it is compliant in accordance with any discharge consent.
					Deeper Groundwater (Berriedale Sandstone Formation)	It is unlikely that the Berriedale Sandstone Formation would be significantly affected by contaminants within perched groundwater owing to the presence of Glacial Till drift deposits.
Option 1: Local Carriageway Widening	Ground gases dissolved in perched groundwater generated from sources up-hydraulic gradient of TP16 – likely to be derived off site, potentially associated with the graveyard)	➧	Migration and diffusion via permeable strata and through dissolution, diffusion and migration within perched groundwater flow	➧	Future Site Users including Construction Workers and maintenance workers. Development Infrastructure Off-site Receptors	Maintenance workers are only considered to be at risk if working within confined spaces such as manhole chambers.
Option 1: Local Carriageway Widening	Contaminants within and leaching of contaminants from Made Ground/		Direct contact pathways (ingestion, inhalation, dermal contact)		Future Site Users including construction workers and	

Option Affected	Contaminant Source		Pathway		Receptor	Comments
& Option 2: Carriageway Realignment	other contamination not already identified from the preliminary ground investigation				maintenance workers.	
	Potential diffuse contamination from farming practices within rough pasture land including:	➧	Ingestion of contaminated soil Inhalation/ingestion of soil derived dust Inhalation of organic vapours Direct contact with soils/dusts Plant uptake	➧	Future Site Users Construction Workers Development Infrastructure Off-Site Receptors Flora and Fauna	

9 Recommendations for Further Ground Investigation

The trial pitting works were a feasibility stage investigation to establish the general nature of the ground conditions across the site. Now that the general ground conditions are known it is possible to scope a second, more comprehensive ground investigation. The findings of the second phase of ground investigation would be used to inform the detailed geotechnical design of the Scheme.

9.1 Field Work

Table 9.1 below summarises the recommendations for the second phase of ground investigation field work. Locations of the exploratory holes are shown on Figure 5 in Appendix 4.

Table 9.1 Recommendations for Further Ground Investigation

Borehole No.	Type (see note 1)	Purpose	Depth	Sampling (see note 2)	In-situ testing
1	Sonic/CP	In-situ soil properties for design of reinforced earth	10m (or rockhead if shallower)	Standard soil sampling	SPTs
2	Sonic/CP	In-situ soil properties for design of reinforced earth	10m (or rockhead if shallower)	Standard soil sampling	SPTs
3	Rotary cored	Rock properties for rock cutting design, excavatability and re-use. Cut depth = 8.2m	12m (approx depth of cutting +3m)	Rock core	Down hole geophysics, Packer impression test
4	Rotary cored	Rock properties for rock cutting design, excavatability and re-use. Cut depth = 8.2m	12m (approx depth of cutting +3m)	Rock core	Down hole geophysics, Packer impression test
5	Sonic/CP with rotary core follow on (if rock is encountered)	Establish rockhead level, and rock properties if rock is encountered in the cutting depth. Cut depth = 7.4m	11m (approx depth of cutting +3m)	Standard soil sampling &rock core (if rock is encountered)	SPTs Down hole geophysics, Packer impression test
6	Sonic/CP with rotary core follow on (if rock is encountered)	Establish rockhead level, and rock properties if rock is encountered in the cutting depth. Cut depth = 7.4m	11m (approx depth of cutting +3m)	Standard soil sampling &rock core (if rock is encountered)	SPTs Down hole geophysics, Packer impression test
7	Sonic/CP with rotary core follow on (if rock is	Investigate area not covered in trial pitting due to difficult access. Cut slope design and	9m (approx depth of cutting +3m)	Standard soil sampling &rock core (if rock is encountered)	SPTs

Borehole No.	Type (see note 1)	Purpose	Depth	Sampling (see note 2)	In-situ testing
	encountered)	soil/rock re-use. Cut depth = 5.3m			
8	Sonic/CP with rotary core follow on (if rock is encountered)	Investigate area not covered in trial pitting due to difficult access. In-situ properties for design of reinforced earth.	10m (or rockhead if shallower)	Standard soil sampling &rock core (if rock is encountered)	SPTs
9	Sonic/CP	In-situ soil properties for design of reinforced earth	10m (or rockhead if shallower)	Standard soil sampling	SPTs
10	Sonic/CP	In-situ soil properties for design of reinforced earth	10m (or rockhead if shallower)	Standard soil sampling	SPTs
11	Sonic/CP	In-situ soil properties for design of reinforced earth	10m (or rockhead if shallower)	Standard soil sampling	SPTs
12	Sonic/CP	Establish nature of retaining wall backfill to inform design of tie-in of reinforced earth.	To base of wall +5m (or rockhead if shallower)	Standard soil sampling	SPTs
13	Sonic/CP	Investigate area not covered in trial pitting due to difficult access. In-situ properties for design of reinforced earth.	10m (or rockhead if shallower)	Standard soil sampling	SPTs
14	Rotary open hole	Determine ground conditions at toe of wall for local widening option. Determine contaminant conditions present for local widening option down hydraulic gradient of TP16 where contamination in the perched groundwater has been identified.	10m (or rockhead if shallower) and to 1m below groundwater Borehole to be installed with 50mm standpipe to base	Standard soil sampling. Sampling of groundwater for contamination analysis (including dissolved gases)	SPTs
BH15	Sonic/CP	Determine contaminant conditions present for local widening option up-hydraulic gradient of TP16 where contamination in the perched groundwater has been identified.	Borehole to be installed with 50mm standpipe. Response zone within grey slightly clayey gravelly sand ~ 1.1 - 2.6mbgl	Sampling of soils and groundwater for contamination analysis (including dissolved gases)	SPTs
PC1	Pavement core	Establish pavement make-up for tie-in design	1m	Core of pavement	None
PC2	Pavement core	Establish pavement make-up for tie-in design	1m	Core of pavement	None
PC3	Pavement core	Establish pavement make-up for tie-in design	1m	Core of pavement	None
PC4	Pavement core	Establish pavement make-up for tie-in design	1m	Core of pavement	None

Borehole No.	Type (see note 1)	Purpose	Depth	Sampling (see note 2)	In-situ testing
MC 1	Wall core	Establish thickness of retaining wall for structural assessment and tie-in design	Wall thickness	Core of wall masonry and concrete	None
MC2	Wall core	Establish thickness of retaining wall for structural assessment and tie-in design	Wall thickness	Core of wall masonry and concrete	None
MC3	Wall core	Establish thickness of retaining wall for structural assessment	Wall thickness	Core of wall masonry and concrete	None
MC4	Wall core	Establish thickness of retaining wall for structural assessment	Wall thickness	Core of wall masonry and concrete	None
TP01	Trial Pit	Allow visual inspection of existing foundation and founding strata	As determined by foundation (approx 1m – 2m)	None	None

Other Items:

- Undertake further detailed inspection of the exposed rock faces (shoreline cliffs and roadside rock cut) to confirm findings of the feasibility stage inspections and obtain information to permit detailed design of the rock cutting slopes.
- Ecological survey prior to any vegetation clearance and archaeological survey/watching brief if required for works near the cemetery.

Notes:

1. Trial pitting found the ground conditions to be sand and gravel with occasional cobbles and boulders. Visual inspection suggests it is a dense material. Cable percussion may struggle to advance through the dense granular material, especially in places with large obstructions. Sonic drilling should be considered to minimise chiselling time, and if a tracked sonic rig is available it may help ease access to difficult locations on the cliff-side slopes.

2. Standard soil sampling comprises bulk and disturbed samples at 1m spacing to 5m bgl thereafter at 1.5m spacing. Soil sampling for contamination purposes to be performed within top 1m plus wherever contamination has been identified. U100 samples should be undertaken in cohesive strata at these intervals.

9.2 In-situ and Laboratory Testing

In-situ and laboratory testing will be determined by the strata encountered in the exploratory holes and the samples taken during the site works. However, as a minimum the laboratory testing scheduled should aim to address the unknowns and areas with limited data identified in this report.

9.2.1 Soil testing

Laboratory testing undertaken in the preliminary ground investigation has established that the superficial deposits on site have high fines content, may be suitable as Class 1 and /or Class 2 fill if the moisture contents can be controlled but are unlikely to be suitable as Class 6I or 6J fill to reinforced earth. More re-use testing in future would be recommended to confirm these findings.

In terms of in-situ properties less is known about the superficial deposits as no in-situ tests (ie. SPTs) or undisturbed samples were obtained during the trial pitting. For the reinforced earthfill designs at either end of the scheme accurate knowledge of the in-situ properties of the underlying glacial till will be vital for ground modelling and analysis. As such it is recommended that SPTs be undertaken in BH9, BH10, BH11 in the south and BH 01 and BH13 in the north. In addition undisturbed (U100) samples should be obtained in the deeper glacial till to allow triaxial testing to establish total and effective shear strength parameters as well as consolidation parameters.

If the local widening option was favoured there is currently little known about the in-situ properties of the soil behind the existing retaining wall, so SPTs should be undertaken in BH15 to obtain some in-situ data.

If the soil nail option was to be pursued a number of tests are commonly required such as grading, relative density (usually obtained from SPT), aggressivity to concrete (BRE SD1) and steel, classification and effective stress shear strength (direct shear in a large drained shear box test).

Similar testing would be required to inform the design of a bored piled embedded retaining wall. Again, undisturbed (U100) samples should be obtained if deep deposits of glacial till are encountered in order that triaxial testing can be undertaken to establish total and effective shear strength parameters. As the piles would have to be embedded into bedrock then investigation of rock condition, rockhead profile and rock properties for design would be required. Detailed information on groundwater levels would also be required from piezometers.

At this feasibility stage there have been no discussions about drainage systems such as soakaways, infiltration ponds and the like. If at detailed design stage such drainage measures were proposed soakaway tests or borehole permeability tests should be undertaken to determine permeability at the location of these features.

9.2.2 Rock testing

The preliminary ground investigation has identified that the cutting from Ch 200m to Ch 280m will be largely in rock. As such laboratory testing should be undertaken on rock cores recovered from BH03, BH04 and, if rock is encountered, from BH05 and BH06. The testing should aim to inform the cutting design, both in terms of excavatability during construction and stability during its Design life, although this will largely be controlled by the rock mass characteristics (discontinuities etc). In addition testing should also be undertaken to establish the re-use properties of the excavated rock and thereby maximise its potential for use within the scheme.

No Uniaxial Compressive strength testing was possible in the preliminary ground investigation, so this would be strongly recommended in any future work. Further point load tests should also be undertaken in order to develop a site specific correlation between Is(50) and UCS. The UCS values can be used in conjunction with other rock mass properties to determine the excavation methods likely to be required to form the rock cutting.

The preliminary ground investigation found that the rock sampled from near the site would be suitable for re-use as capping or sub-base or as earthworks fill. Re-use tests such as Los Angles co-efficient, magnesium sulphate soundness and water absorption should be undertaken on the rock cores from BH03 and BH04 to confirm if the rock in the cutting is similarly acceptable.

9.2.3 Contamination Testing

Option 1: Carriageway Widening

The preliminary ground investigation and associated contamination assessment has identified the presence of diesel- and mineral-range hydrocarbons (>C10-C35 aliphatic range) within saturated soils (and perched groundwater) at TP16. Trace concentrations of a number of volatile organic compounds and lighter-end hydrocarbons (in the C8-C10 aromatic range).

A preliminary assessment of limited samples collected and analysed from this area has established the presence of significant contamination of the DRO and MOR-range hydrocarbons for future site users *if* free product is present. From an initial observation, however, this is deemed to be unlikely. A number of more volatile compounds have additionally been recorded within the sample at this location that have not been recorded at significantly elevated concentrations for human health. These may, however, be causing the dissolution of gases observed during fieldwork although there is a possibility that carbon dioxide and/or methane is additionally present.

It is considered that the contamination is likely to be migrating within perched groundwater from up-hydraulic gradient of the site (i.e. from the north). The exact source of the contamination is unknown although may potentially be associated with the adjacent graveyard or a hydrocarbon spill up-hydraulic gradient of the site.

Contamination identified at TP16 was not delineated during the ground investigation. It is possible that this material may be excavated in line with proposals for a cutting (to a depth of around 5m bgl) at this location. This extends to below the level of the grey slightly clayey gravelly sand where the odour, gassing and DRO, MRO and volatile contamination was identified. There is the likelihood that this material shall be taken off site for disposal/reuse.

Further delineation of the soils within this area is recommended along with sampling of groundwater for hydrocarbons, volatile organic compounds and dissolved ground gases, at locations both up- and down-hydraulic gradient of the site.

It will be necessary to establish:

- how the contamination present may affect the quality of infiltrated water collecting within the drains (for subsequent discharge purposes);
- the ground gas concentrations present in this area to establish potential risks to future receptors within any manholes and behind the retaining wall structure;

- Potential disposal/reuse options for the material off-site.

The remainder of the site should be subject to confirmatory tests including testing in association with the Waste Acceptance Criteria (WAC) to establish options for reuse or disposal of the excavated material. There will not be an option to reuse the material elsewhere within the scheme within the proposed carriageway widening.

Option 2: Carriageway Realignment

No significant contamination was identified from the exploratory holes sampled and analysed for contamination purposes and a visual and olfactory assessment did not identify the presence of any potential contamination and/or Made Ground.

The remainder of the site should be subject to confirmatory tests for a general suite of inorganic and organic testing to establish material reuse options of within the scheme, particularly where any made ground or other potential contamination is identified.

Testing in association with WAC should be performed where material is to be disposed off-site to landfill.

9.3 Instrumentation and Monitoring

Groundwater monitoring in the form of piezometers and standpipes are recommended in order to define the groundwater level across the site, particularly in the rock cutting, beneath the proposed reinforced earth embankments at the northern and southern tie-ins and in front of the cemetery.

Piezometers/standpipes should be installed within the rock cutting to determine whether there is water flow along discontinuities in the rock. At either end of the cutting piezometers should be installed to assess the ground water level and confirm the need for slope face drainage.

Under the reinforced earth fill the groundwater profile will be a critical parameter for accurate modelling, especially with the fill being constructed on sidelong ground. As such piezometers should be installed. Knowledge of the existing water table will also inform consolidation estimates.

In front of the cemetery the groundwater levels have to be established to determine the hydraulic gradient. Standpipes (50mm diameter) and piezometers should be installed to monitor groundwater levels and allow sampling. Gas bungs on top of the pipe will allow gas monitoring.

9.4 Cost Estimate of the Proposed Ground Investigation

The estimated cost of the work (based on 2010 rates) is in the order of £80,000 to £90,000 and includes costs for site work, laboratory testing and geo-environmental testing.

10 Recommendations for Future Topographic Survey

The topographical information available at this stage is limited. It is recommended that a detailed topographic survey be undertaken for use in the detailed design stage.

To progress the required scheme to detailed design and provide details to a scale of 1:500 a topographical survey has been scoped and is shown in Figure 6. This indicates that a total area of 5ha needs to be surveyed over the whole scheme at an approximate cost of £15,000.00

11 Conclusion

The purpose of the 2010/2011 work was to ascertain whether either the re-alignment option or the local widening option could be feasibly taken forward to the next stage of design. This report has considered the road geometry and design standards as well as the geotechnical aspects of both the local widening and the re-alignment options. The following are the main findings of the report:

- The ground conditions are reasonably favourable for both options.
- Ground conditions were found to be glacial till (silty clayey gravelly sand) or weathered rock (sand/gravel) overlying Berriedale Flagstones.
- The majority of the 9m deep cutting in the re-alignment option would be in rock, with slopes of up to 4m – 5m being formed in superficial deposits only towards the south and north ends of the cutting.
- The main concern about the re-alignment option lies in the global stability of the reinforced earthfill embankments (or any type of fill or structure), which are up to 10m high, on the sidelong cliff-side glacial till slopes at the northern and southern tie-ins with the existing A9.
- If local widening was favoured then the design could be largely driven by the constructability of the proposed solutions, as well as consideration of the ground conditions
- Further ground investigation and topographic survey work is required for both options.
- A total area of 5ha needs to be surveyed over the whole scheme at an approximate cost of £15,000.00.
- The estimated cost of a future detailed ground investigation is in the order of £80,000 to £90,000.
- For the re-alignment option a Scheme Cost of £2.3M has been calculated.

APPENDIX 1

- Trial Pit Logs for TP 01 to TP 16 undertaken in February 2011
- Figure 3 - Trial pit location plan

TRIAL PIT LOG

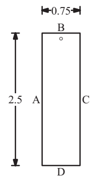
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP01**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 311990.0 N 922849.0	**Ground Level:** 79.30 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	**Backfill/ Instrument**
			79.00	(0.30) 0.30	Grass over TOPSOIL		
0.40	D JAR D VIAL				Grey brown clayey gravelly SAND. Gravels are fine to coarse sub-angular to sub-rounded. ... seepage at 0.65m bgl on north (uphill face) ... below 1.7m bgl frequent sub-rounded to angular cobbles and occasional sub-rounded to angular boulders		1
1.00	D 001 B 002						
				(3.00)			
2.00	D 003 B 004						
			76.00	3.30			
					End of Trial Pit		

Groundwater Observations

Depth	Flow
0.60	Sheen of water seeping from north face

Orientation



Method, Equipment and Remarks

Pit stopped at 3.3m bgl on boulder/obstruction and when machine was near full reach. Hard digging for full depth.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

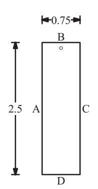
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP02**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 311992.0 N 922814.0	**Ground Level:** 77.30 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	**Backfill/ Instrument**
			76.80	(0.50) 0.50	Grass over TOPSOIL		
1.00	D 001 B 002		76.00	(0.80) 1.30	Orange brown very sandy silty slightly clayey GRAVEL with frequent rounded to sub-angular cobbles. Gravel is fine to coarse rounded to angular.		
2.00	D 003 B 004		74.70	(1.30) 2.60	Orange grey very gravelly silty clayey SAND. Frequent angular to sub-rounded cobbles. ... damp		
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**

Orientation



Method, Equipment and Remarks

Pit stopped at 2.6m bgl when ground became too hard to excavate.
Hard digging for full depth.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

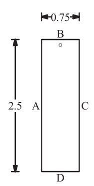
Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP03** Sheet: 1 of 1
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312022.0 N 922813.0	**Ground Level:** 79.00 (m)	
Contractor:	**Engineer:**		

Samples & Tests			Strata				Backfill/ Instrument
Depth	Type No	Test Result	Reduced Level	Depth (Thickness)	Description	Legend	
			78.75	(0.25) 0.25	Grass over TOPSOIL		
1.00	D 001 B 002		77.60	(1.15) 1.40	Brown red clayey silty SAND AND GRAVEL. Gravels are fine to coarse angular to sub-angular. Frequent angular to sub-rounded cobbles and occasional angular flaggy boulders (of Sandstone).		
					End of Trial Pit		

Groundwater Observations		Orientation	Method, Equipment and Remarks	
Depth	Flow		Pit stopped at 1.6m bgl on possible rockhead. Hard digging for full depth. **Method / Equipment:** VOLVO ECR88 9T digger	**Stability:** Stable **Shoring:** None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

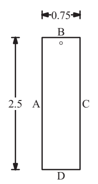
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP04**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312021.0 N 922786.0	**Ground Level:** 78.30 (m)	
Contractor:		**Engineer:**	Sheet: 1 of 1

Samples & Tests			Strata				Backfill/ Instrument
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	
			78.10	(0.20) 0.20	Grass over TOPSOIL		
0.40 0.50	D 001 D JAR D VIAL B 002		77.70	(0.40) 0.60	Brown red slightly clayey very gravelly SAND. Gravels are fine to coarse angular to sub-angular, occasionally rounded.		
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**

Orientation



Method, Equipment and Remarks

Pit stopped at 0.6m bgl on possible rockhead.
Hard digging for full depth.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

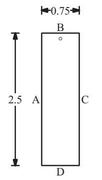
Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

Project: Berriedale Braes	**Job No:** S094BJG - A9 Helmsdale	Trial Pit No.
Date: 17-02-2011/17-02-2011 **Co-ordinates:** E 312070.0 N 922786.0	**Ground Level:** 79.30 (m)	**TP05**
Contractor: **Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				Backfill/ Instrument
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	
			79.10	(0.20) 0.20	Grass over TOPSOIL		
			78.80	(0.30) 0.50	Red brown slightly clayey very gravelly SAND. Gravels are fine to coarse angular (of Sandstone). Frequent angular flaggy cobbles and boulders (of Sandstone).		
0.50	B 001				End of Trial Pit		

Groundwater Observations		Orientation	Method, Equipment and Remarks	
Depth	**Flow**		Pit stopped at 0.5m bgl on possible rockhead. Hard digging for full depth. Pit extended to be 8m long, rockhead present along full length. **Method / Equipment:** VOLVO ECR88 9T digger	**Stability:** Stable **Shoring:** None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

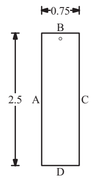
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP06**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312046.0 N 922767.0	**Ground Level:** 77.60 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				Backfill/ Instrument
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	
			77.40	(0.20) 0.20	Grass over TOPSOIL		
			77.10	(0.30) 0.50	Red brown slightly clayey gravelly SAND. Gravels are fine to coarse angular (of sandstone).		
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**

Orientation



Method, Equipment and Remarks

Pit stopped at 0.5m bgl on possible rockhead.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

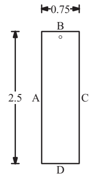
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP07**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312099.0 N 922757.0	**Ground Level:** 75.00 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	**Backfill/ Instrument**
			74.80	(0.20) 0.20	Grass over TOPSOIL		
1.00	D 001 B 002				Brown red orange very sandy silty clayey GRAVEL. Gravels are fine to coarse sub-rounded to angular of mixed lithology. Frequent angular to sub-rounded cobbles. Occasional angular flaggy boulders (of sandstone). ... 0.5m bgl slight seepage on north (uphill) face		
1.50	B 003		73.40	(1.40) 1.60			
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**
0.50	Slight seepage on north (uphill) face

Orientation



Method, Equipment and Remarks

Pit stopped at 1.6m bgl on possible rockhead.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

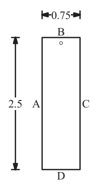
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP08**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312081.0 N 922739.0	**Ground Level:** 69.30 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				Backfill/ Instrument
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	
			69.00	(0.30) 0.30	Grass over TOPSOIL		
0.30	D JAR D VIAL				Brown light red silty clayey SAND AND GRAVEL. Gravels are fine to coarse angular to rounded of mixed lithology. .. from 0.7m bgl occasional angular flaggy boulders of sandstone		
1.00	D 001 B 002			(1.30)			
1.20	B 003		67.70	1.60			
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**

Orientation



Method, Equipment and Remarks

Pit stopped at 1.6m bgl on large boulder obstruction/possible rockhead.
Hard digging for full depth.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

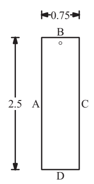
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP09** Sheet: 1 of 1
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312089.0 N 922717.0	**Ground Level:** 70.60 (m)	
Contractor:	**Engineer:**		

Samples & Tests			Strata				
Depth	Type No	Test Result	Reduced Level	Depth (Thickness)	Description	Legend	Backfill/ Instrument
			70.35	(0.25) 0.25	Grass over TOPSOIL		
1.00	D 001 B 002				Brown light red very gravelly silty slightly clayey SAND. Gravels are fine to coarse angular to sub-rounded. Occasional angular to sub-rounded cobbles and boulders. ... 0.5m bgl obstruction (large boulder or rockhead)		
2.00	D 003 B 004		67.60	(2.75) 3.00			
			67.10	(0.50) 3.50	Dark grey brown fine very clayey gravelly SAND. Gravels are fine to medium of mixed lithology.		
3.50	D 005				End of Trial Pit		

Groundwater Observations

Depth	Flow

Orientation



Method, Equipment and Remarks

Pit stopped at 3.5m bgl when ground became too hard to excavate and machine as near full reach.
Very hard digging for full depth.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

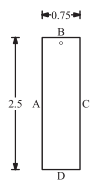
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP10**
Date: 17-02-2011/17-02-2011	**Co-ordinates:** E 312109.0 N 922736.0	**Ground Level:** 71.00 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	**Backfill/ Instrument**
				(0.30)	Grass and gorse over TOPSOIL		
0.25	D JAR D VIAL		70.70	0.30			
					Brown red very sandy silty slightly clayey GRAVEL. Gravels are sub-angular to angular occasionally rounded to sub-rounded. Frequent angular to sub-rounded cobbles and boulders (of sandstone). ... 1.0m bgl very damp and seepage from north (uphill) face		
1.00	D 001 B 002			(1.40)			
			69.30	1.70			
					Grey brown silty slightly clayey SAND AND GRAVEL. Gravels are fine to coarse angular to sub-rounded. Frequent angular to sub-rounded cobbles andf occasional boulders (of sandstone). ... very damp throughout ... seepage at 3.5m bgl, steady inflow		
2.00	D 003 B 004						
				(2.00)			
3.20	D 005 B 006						
			67.30	3.70			
					End of Trial Pit		

Groundwater Observations

Depth	Flow
1.00	Damp. Slow seepage from north (uphill) face.
3.50	Very damp. Steady inflow

Orientation



Method, Equipment and Remarks

Pit stopped at 3.7m bgl when ground became too hard to excavate and machine was near full reach.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Slight collapses at 1mbgl due to wet sands falling off side walls

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

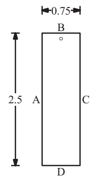
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP11**
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312108.0 N 922693.0	**Ground Level:** 52.00 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				Backfill/ Instrument
Depth	Type No	Test Result	Reduced Level	Depth (Thickness)	Description	Legend	
			51.60	(0.40) 0.40	Grass and gorse over TOPSOIL		
1.00	D 001 B 002		49.50	(2.10) 2.50	Light grey mottled orange brown gravelly silty clayey SAND with rare angular to rounded cobbles. Gravels are fine to coarse angular to sub-rounded of mixed lithology. Sand is fine to medium.		1 (water strike)
2.80	D 003 B 004		48.30	(1.20) 3.70	Dark brown black mottled orange gravelly silty clayey SAND. Gravels are sub-angular to sub-rounded. Occasional sub-angular to sub-rounded cobbles. Sand is fine. ... from 3.5m bgl occasional boulders (of sandstone) ... 2.5m bgl slow seepage from west (uphill) face		
					End of Trial Pit		

Groundwater Observations

Depth	Flow
2.50	Seepage from west (uphill) face

Orientation



Method, Equipment and Remarks

Pit stopped at 3.7m bgl due to boulder obstructions and when machine was near full reach.
Hard digging from 2.5m bgl

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

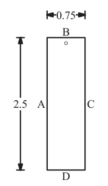
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP12** Sheet: 1 of 1
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312076.0 N 922679.0	**Ground Level:** 52.60 (m)	
Contractor:		**Engineer:**	

Samples & Tests: Depth	Type No	Test Result	Strata: Reduced Level	Depth (Thickness)	Description	Legend	Backfill/ Instrument
			52.30	(0.30) 0.30	Bracken and root mass		
0.35	D 001 D JAR D VIAL		52.10	(0.20) 0.50	TOPSOIL		
1.50	B 002 D 003		50.40	(1.70) 2.20	Light grey mottled orange brown gravelly silty clayey SAND. Sand is fine to medium.		
			49.70	(0.70) 2.90	Dark brown orange gravelly silty clayey SAND. Sand is fine to medium.		
3.00	B 004 D 005		48.60	(1.10) 4.00	Dark brown gravelly silty clayey SAND. Gravels are fine to coarse rounded to sub-angular of mixed lithology. Sand is fine. ...3.5m bgl slow seepage from south face		1
					End of Trial Pit		

Groundwater Observations

Depth	Flow
3.50	Slow seepage on south face

Orientation



Method, Equipment and Remarks

Pit stopped at 4m bgl when ground became too hard to excavate and machine was at full reach.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

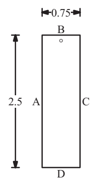
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP13** Sheet: 1 of 1
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312102.0 N 922675.0	**Ground Level:** 50.60 (m)	
Contractor:	**Engineer:**		

Samples & Tests			Strata				Backfill/ Instrument
Depth	Type No	Test Result	Reduced Level	Depth (Thickness)	Description	Legend	
			50.30	(0.30) 0.30	Bracken over TOPSOIL		
0.50	D 001 B 002 D JAR D VIAL				Grey brown mottled orange gravelly silty clayey SAND. Gravels are sub-angular to sub-rounded, occasionally angular, of mixed lithology. Sand is fine to medium. ... 1m and 2m bgl slow seepage from eastern face		
1.50	D 003 B 004			(2.10)			
2.30	D 005 B 006		48.20	2.40			
				(1.00)	Dark brown black mottled orange gravelly silty clayey SAND. Gravels are sub-angular to sub-rounded, occasionally angular, of mixed lithology. Occasional sub-angular to sub-rounded boulders and cobbles of mixed lithology. Sand is fine. ... 2.4m bgl slow seepage from eastern face		
3.30	D 007 B 008		47.20	3.40			
					End of Trial Pit		

Groundwater Observations

Depth	Flow
1.00	Slow seepage/sheen on east face
2.00	Slow seepage/sheen on east face
2.40	Slow seepage/sheen on east face

Orientation



Method, Equipment and Remarks

Pit stopped at 3.7m bgl when ground became too hard to excavate.
Hard digging from 2.4m bgl

Method / Equipment: VOLVO ECR88 9T digger

Stability: Slight collapses at 1m, 2m and 2.4m bgl due to wet sands falling off side walls

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

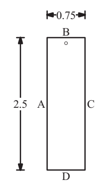
TRIAL PIT LOG

Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP14** Sheet: 1 of 1
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312068.0 N 922651.0	**Ground Level:** 46.60 (m)	
Contractor:	**Engineer:**		

Samples & Tests			Strata				Backfill/ Instrument
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	
			46.40	(0.20) 0.20	Bracken and rootmass		
0.40	D 001 D JAR D VIAL		46.10	(0.30) 0.50	TOPSOIL		
1.50	B 002 D 003		44.20	(1.90) 2.40	Light grey mottled orange brown gravelly silty clayey SAND. Occasional sub-angular to sub-rounded cobbles of mixed lithology. Sand is fine to medium.		
3.00	B 004 D 005		42.60	(1.60) 4.00	Dark grey brown very gravelly silty clayey SAND. Gravels are fine to coarse angular to sub-rounded. Sand is fine. ... from 3.2m bgl occasional angular flaggy boulders of sandstone [Looks like occasional gravels in dense/stiff very sandy clay matrix]		
					End of Trial Pit		

Groundwater Observations	
Depth	**Flow**

Orientation



Method, Equipment and Remarks

Pit stopped at 4m bgl when ground became too hard to excavate and machine was at full reach.

Method / Equipment: VOLVO ECR88 9T digger

Stability: Stable

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

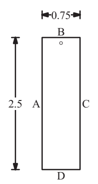
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP15**
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312031.0 N 922651.0	**Ground Level:** 38.00 (m)	
Contractor:	**Engineer:**		Sheet: 1 of 1

Samples & Tests			Strata				
Depth	**Type No**	**Test Result**	**Reduced Level**	**Depth (Thickness)**	**Description**	**Legend**	**Backfill/ Instrument**
			37.65	(0.35) 0.35	Grass over TOPSOIL		
0.40	D JAR D VIAL						
0.70	D 001 B 002		37.00	(0.65) 1.00	Orange brown slightly clayey gravelly SAND (possible made ground due to proximity of retaining wall)		
1.80	D 003 B 004		35.90	(1.10) 2.10	Light grey mottled orange brown very gravelly silty clayey SAND. ... 1m to 1.7m bgl very damp ... 1.7m bgl seepage ... 2.1m bgl boulder		
2.60	D 005 B 006		34.50	(1.40) 3.50	Dark brown black mottled orange very gravelly silty clayey SAND with occasional sub-rounded to sub-angular cobbles of mixed lithology. Gravels are fine to coarse sub-angular to sub-rounded of mixed lithology. Sand is fine. ... 2.1m bgl seepage		
					End of Trial Pit		

Groundwater Observations

Depth	Flow
1.00	Damp
1.70	Slow seepage
2.10	Slow seepage

Orientation



Method, Equipment and Remarks

Pit stopped at 3.5m bgl when ground became too hard to excavate.
Hard digging from 3.0m bgl
Pit 10m south of A9 hairpin retaining wall

Method / Equipment: VOLVO ECR88 9T digger

Stability: Slight at 1.7m bgl due to wet sands falling off side walls

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**

TRIAL PIT LOG

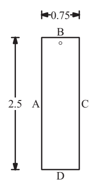
Project: Berriedale Braes		**Job No:** S094BJG - A9 Helmsdale	Trial Pit No. **TP16** Sheet: 1 of 1
Date: 16-02-2011/16-02-2011	**Co-ordinates:** E 312052.0 N 922684.0	**Ground Level:** 61.60 (m)	
Contractor:	**Engineer:**		

Samples & Tests: Depth	Type No	Test Result	Strata: Reduced Level	Depth (Thickness)	Description	Legend	Backfill/ Instrument
				(0.50)	Grass and bracken over TOPSOIL		
0.50	D JAR A D VIAL B		61.10	0.50			
0.80	D 001 B 002			(0.60)	Orange brown slightly clayey very gravelly SAND		
			60.50	1.10			
1.30	D 003 B 004 D JAR C D VIAL D			(1.50)	Grey slightly clayey gravelly SAND. Gravels are fine to coarse rounded to sub-rounded. Occasional rounded to sub-rounded cobbles of mixed lithology. ... very damp. ... from 1m bgl very strong gas/fuel odour ... 1.2m bgl seepage on north (uphill) face		1
2.00	D 005 B 006						
			59.00	2.60			
3.00	D 007 B 008			(0.80)	Dark brown dark grey clayey gravelly SAND. Gravels are fine to coarse sub-angular to sub-rounded of mixed lithology. ... no odour		
			58.20	3.40	End of Trial Pit		

Groundwater Observations

Depth	Flow
1.20	Slow seepage on north (uphill) face

Orientation



Method, Equipment and Remarks

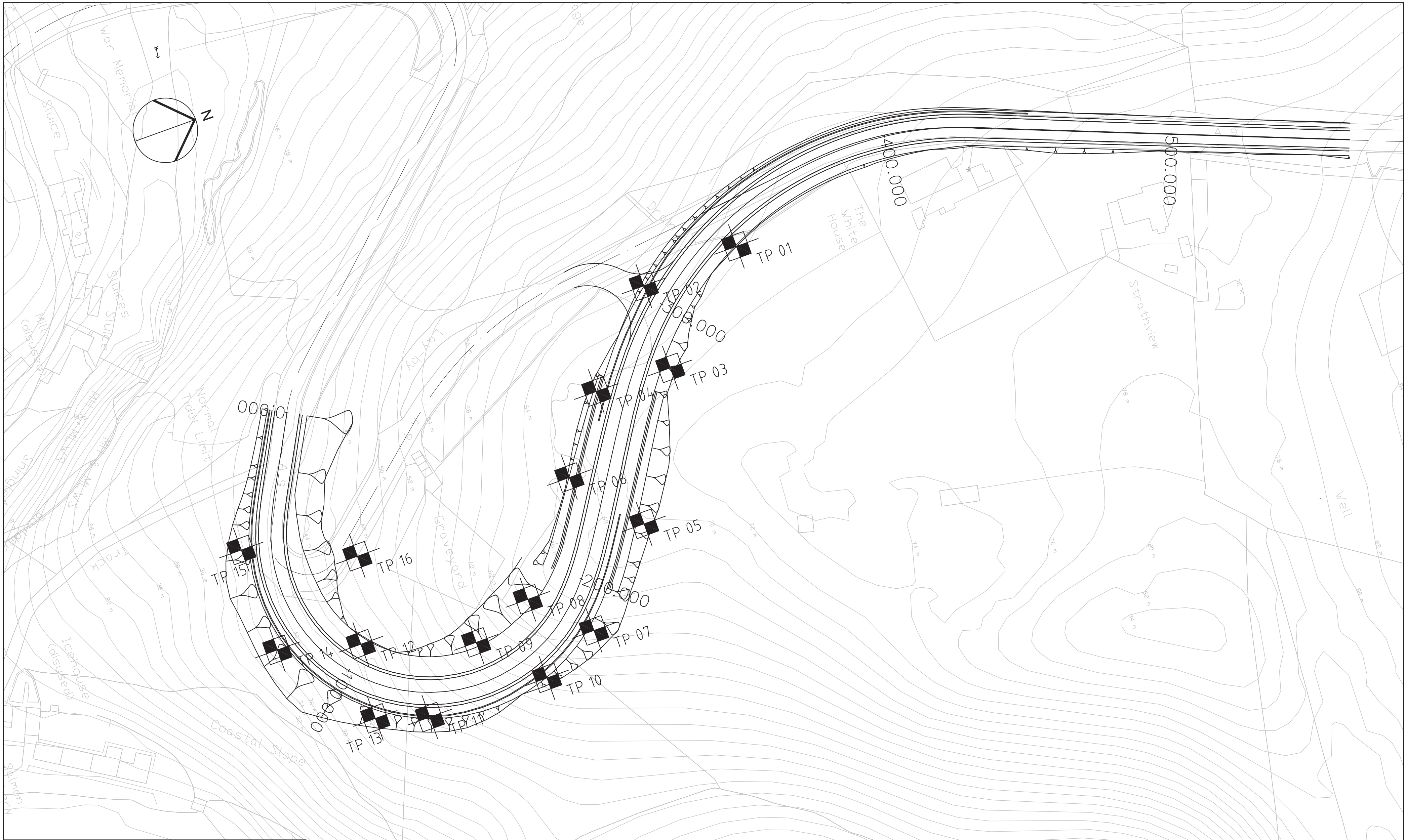
Pit stopped at 3.4m bgl when ground became too hard to excavate.
Very strong fuel odour 1.1m - 2.6m bgl
Pit 3m south of cemetery corner and 10m north of A9 wall

Method / Equipment: VOLVO ECR88 9T digger

Stability: Slight collapses at 1.2m to 2.6m due to wet sands falling off side walls

Shoring: None

Scale: 1:25 @ A4	**Client:** Transport Scotland and The Highland Council	**Logged By:** CM	**Data Checked By:**



Plot Date :
File Name :

TRANSPORT SCOTLAND

Drawing Title

A9 BERRIEDALE BRAES IMPROVEMENTS
GEOTECHNICAL, DESIGN AND CONSTRUCTION ASSESSMENT

2011 GROUND INVESTIGATION LAYOUT PLAN

FIGURE 3

Scale at A3 : 1:1250		
Drw RM	App AB	Rev -
Chk -	Date 04/05/11	Date -

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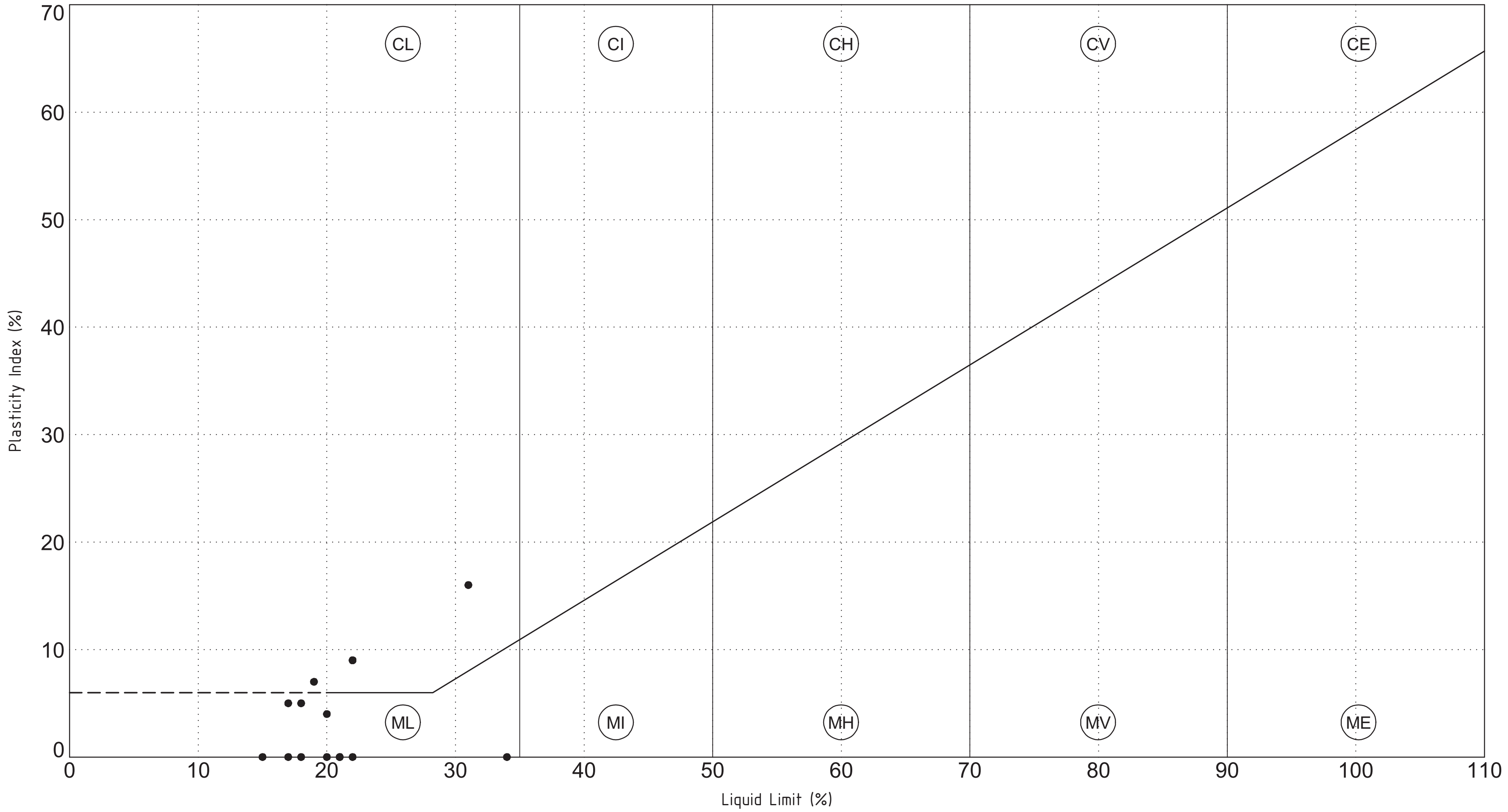
APPENDIX 2

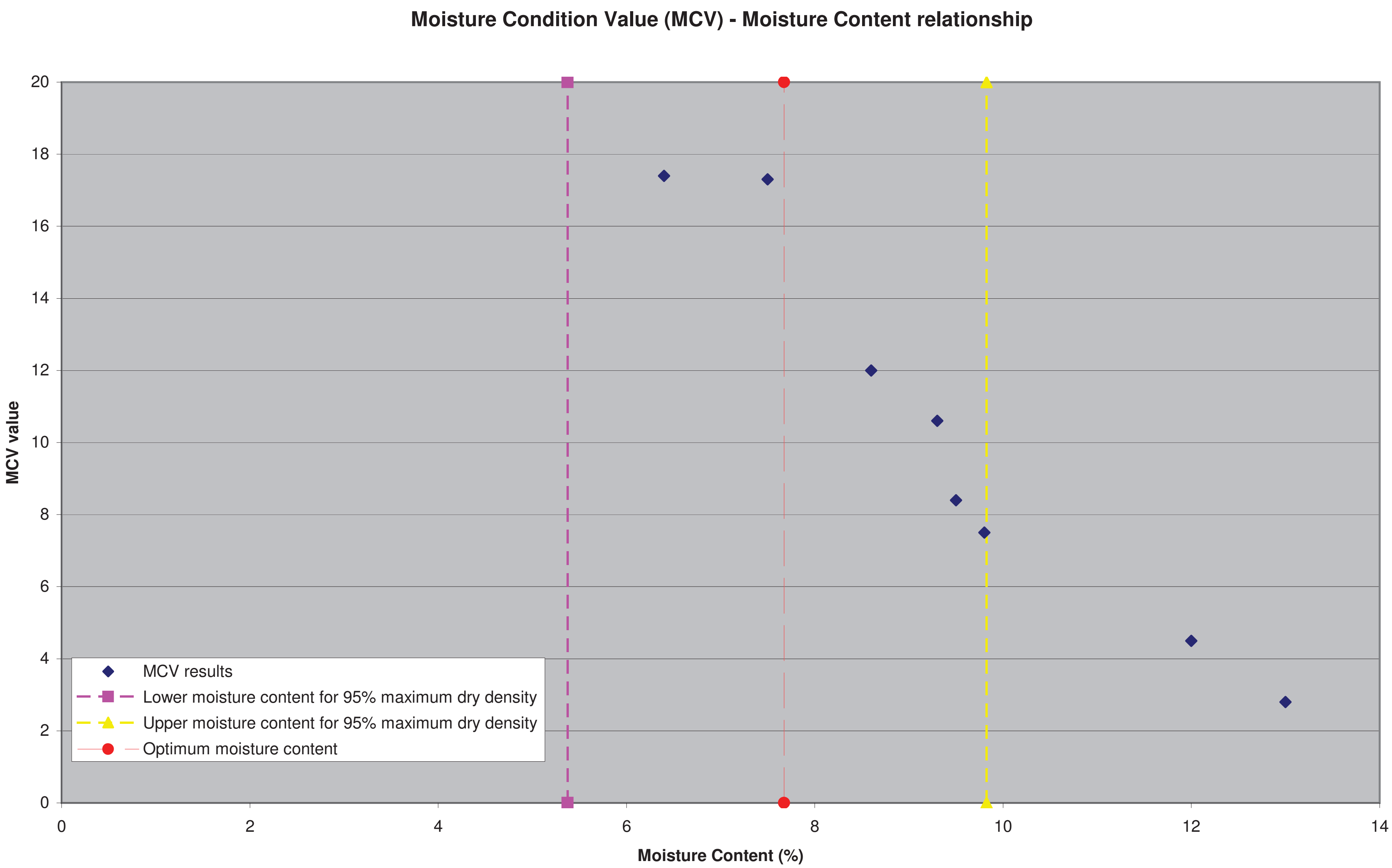
Laboratory Test Results plots:

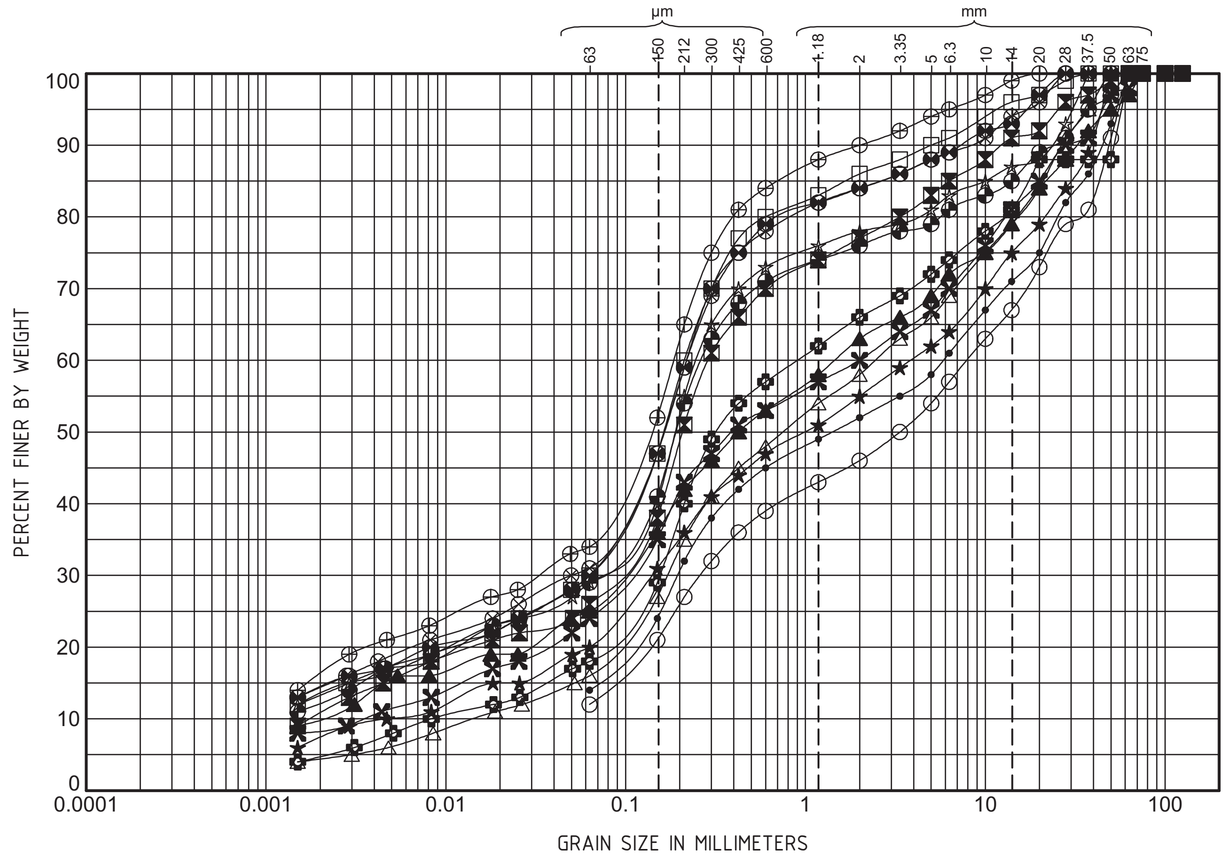
- Plasticity Chart
- MCV v Moisture content relationship
- Particle Size Distribution



PLASTICITY CHART

Geological Unit: **All Units**	Project Number:	S094BJG - A9 Helmsdale
	Project Title:	Berriedale Braes
	Client:	Transport Scotland and The Highland Council


Moisture Condition Value (MCV) - Moisture Content relationship
MCV value
Moisture Content (%)
0
2
4
6
8
10
12
14
16
18
20
MCV results
Lower moisture content for 95% maximum dry density
Upper moisture content for 95% maximum dry density
Optimum moisture content



CLAY	SILT			SAND			GRAVEL			COBBLES
	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	FINE	MEDIUM	COARSE	

	Hole ID	Depth	Samp. No.	D100	D60	D30	D10	%Gravel	%Sand	LL	PL	PI
•	TP02	1.00	2.00	125	5.833	0.194		46.5	38.6			
⧗	TP02	2.00	4.00	125	0.29	0.084	0.002	22.8	51.5			
▲	TP03	1.00	2.00	125	1.457	0.093	0.002	33.6	38.2			
★	TP07	1.00	2.00	125	3.828	0.139	0.005	45.0	35.2			
✖	TP08	1.00	2.00	125	2	0.101	0.004	37.8	36.4			
✿	TP09	2.00	4.00	125	0.9	0.155	0.008	31.5	48.2			
○	TP10	1.00	2.00	125	7.937	0.261		52.1	34.5			
△	TP10	3.20	6.00	125	2.458	0.171	0.014	42.0	42.3			
⊗	TP12	1.50	2.00	125	0.219	0.05		16.0	53.2			
⊕	TP13	1.50	4.00	125	0.186	0.033		10.0	56.2			
□	TP13	3.30	8.00	125	0.212	0.063		14.0	56.4			
◍	TP14	1.50	2.00	125	0.219	0.063		16.0	54.4			
◐	TP14	3.00	4.00	125	0.267	0.068		23.4	47.2			
☆	TP15	1.80	4.00	125	0.252	0.068		22.0	49.4			

PARTICLE SIZE DISTRIBUTION

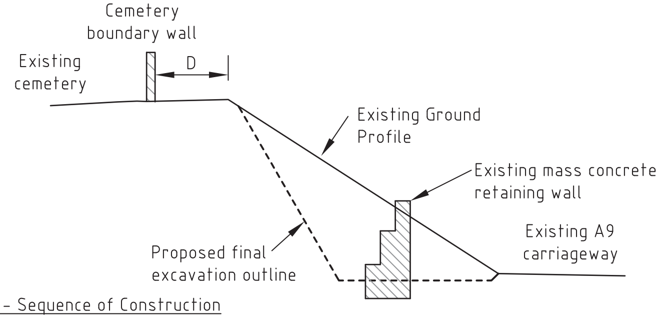
Geological Unit: **All Units**

Project Number:	S094BJG - A9 Helmsdale
Project Title:	Berriedale Braes
Client:	Transport Scotland and The Highland Council

APPENDIX 3

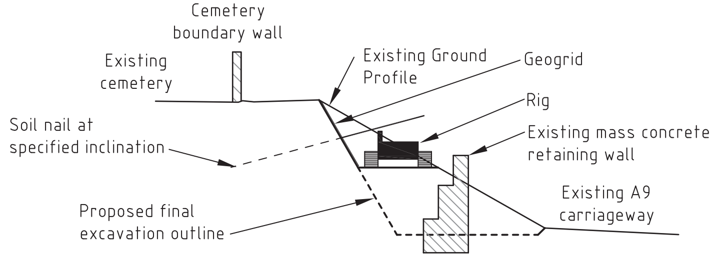
Local Widening Options:

- Figure 4 - Soil Nailed Slope



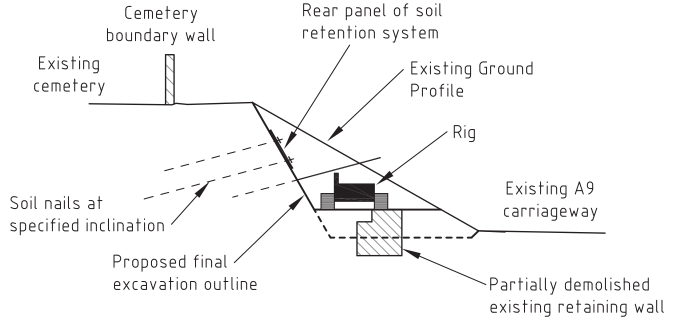
Stage 1 - Sequence of Construction

1. All work shall be undertaken at times dictated by road safety requirements. Traffic management will be in place during the works to keep the southbound carriageway clear of vehicles.
2. Install temporary works to ensure the stability of the cemetery boundary wall.
3. Install monitoring points on cemetery wall and survey daily during the soil nail works to ensure early detection of any movement.



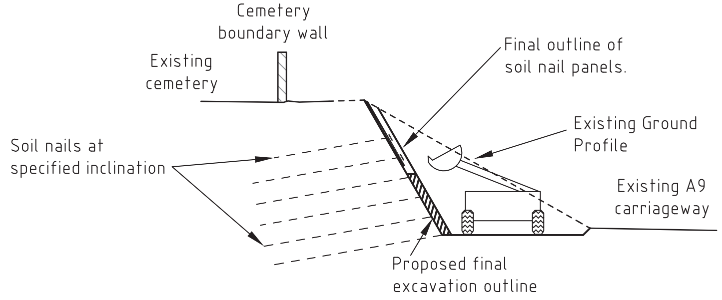
Stage 2 - Sequence of Construction

1. Excavate in one pass from the top down, a bench deep enough to give sufficient width for the drilling rig. Depth of excavation shall not exceed 0.8m.
2. Trim the slope above the bench to 60°. Infill any local loose areas/spalling with no fines concrete. Install slope face drainage as required. Place geogrid and pin to face.
3. Within a short period, drill and grout one row of soil nails. Allow grout to attain 10N/mm2 strength. Place mortar bedding and fix head plates.
4. As a minimum requirement, if the slope is to be left temporarily, the slope works shall be completed to this stage. The Contractor shall be responsible for providing temporary support to any "unfinished" work.



Stage 3 - Sequence of Construction

1. Place soil panels and pin to slope face.
2. Lay geomesh lining across inside of rear soil panels and up and over diaphragms.
3. Place Growing Medium applying light compaction to achieve a firm mass.
4. Fix soil panel lids in place with degradable coir blanket facing inwards.
5. Excavate further benches to allow successive rows of soil nails to be installed together with face support. Depth of excavation shall not exceed 0.8m at any one stage. Excavation for successive rows of nails shall not be permitted until preceding rows have been completed to this stage (item 4).
6. Dismantle the existing retaining wall in stages as the excavation for the soil nail installation progresses.
7. On completion of the soil nailing proof load testing should be undertaken on a number of the installed soil nails.
8. As in stage 2 the Contractor is responsible for providing any temporary support to 'unfinished work'.



Stage 4 - Sequence of Construction

1. Continue the excavation and soil nailing works to the underside of capping layer level.
2. On completion of the nailing works erect the sides of the soil panels and fill with growing medium/topsoil from the lowest panel upwards.
3. Trim and adjust any soil panels which overshoot the crest of the slope.
4. Clear debris from the toe of the slope to allow completion of widened road construction (drainage, capping, sub-base, pavement)

GENERAL NOTES:
1. This drawing is issued as Concept Only.
2. The slope angle and soil nail spacing shown are indicative only and no design has been undertaken.
3. Further ground investigation should be undertaken to obtain more details of the ground condition at the site. The bedrock level is currently unconfirmed, this will be essential to know before developing this local widening soil nail option.
4. A detailed topographic survey of the area is required prior to detailed design.
5. The cemetery is a listed site so Scottish Natural Heritage and/or Highland Council should be consulted during the design stage about the proposed works. The acceptable offset from the top of the new slope to the cemetery wall (shown as 'D' in Stage 1) should be confirmed by Scottish Natural Heritage and/or Highland Council, as will the level of the upper soil nails (to avoid conflict with buried objects in the cemetery).
6. Traffic management is likely to be required during the works but Highland Council/Transerve should be consulted to establish details of this and other requirements for working near a live highway.

Plot Date :
File Name :

Drawing Title

A9 BERRIEDALE BRAES IMPROVEMENTS
GEOTECHNICAL, DESIGN AND CONSTRUCTION ASSESSMENT

LOCAL WIDENING OPTION - SOIL NAILED SLOPES

FIGURE 4

Scale at A3 : 1:200		
Drw RM	App AB	Rev -
Chk -	Date 04/05/11	Date -

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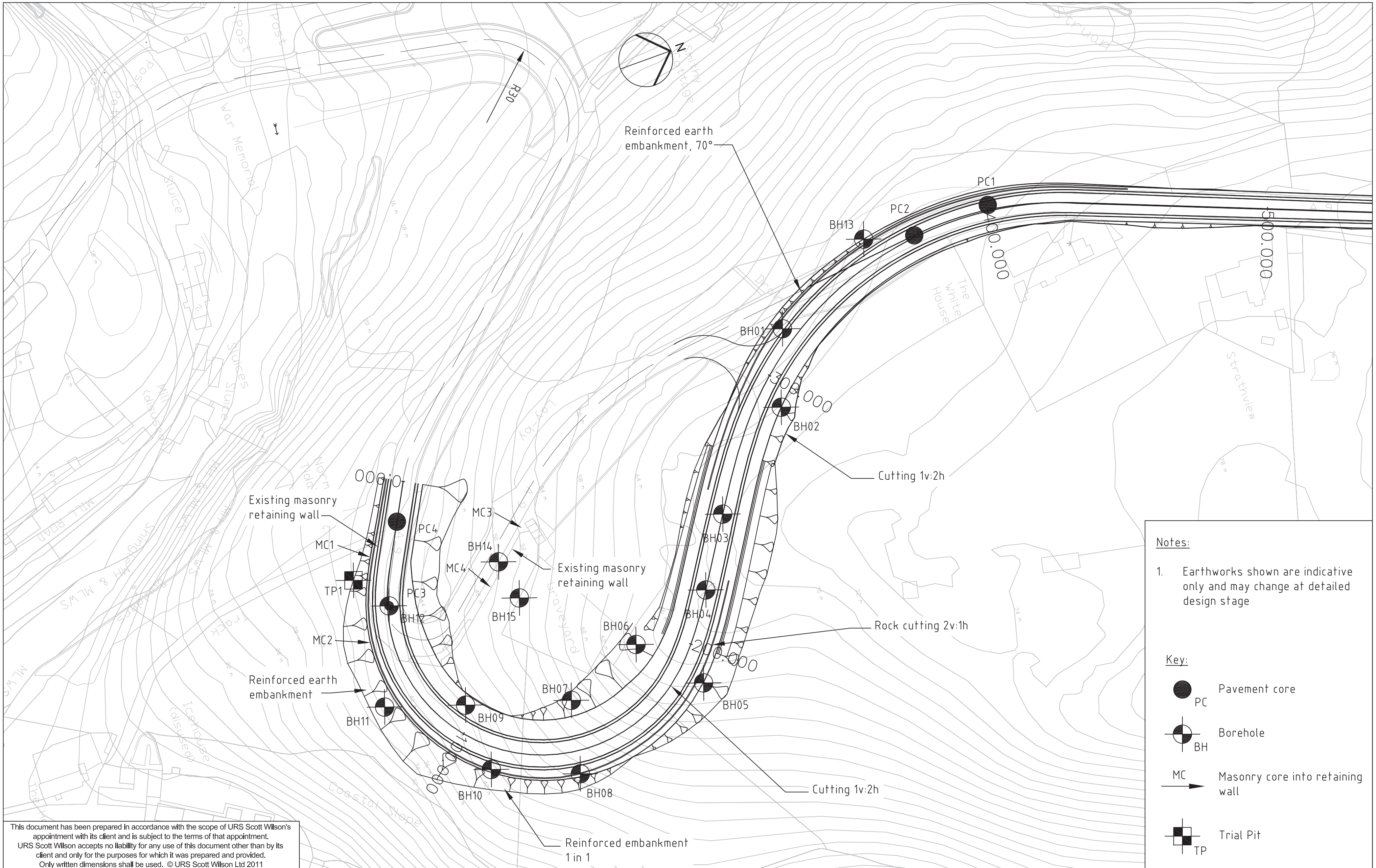
APPENDIX 4

Recommendations for Future Work:

- Figure 5 - Proposed detailed ground investigation, Exploratory hole location plan
- Figure 6 - Detailed Topographical Survey plan



Notes:

1. Earthworks shown are indicative only and may change at detailed design stage

Key:

- PC — Pavement core
- BH — Borehole
- MC — Masonry core into retaining wall
- TP — Trial Pit

Plot Date :
File Name :

TRANSPORT SCOTLAND

Drawing Title

A9 BERRIEDALE BRAES IMPROVEMENTS
GEOTECHNICAL, DESIGN AND CONSTRUCTION ASSESSMENT

PROPOSED FURTHER DETAILED GROUND INVESTIGATION

FIGURE 5

Scale at A3 : 1:1250		
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Chk -	Date 04/05/11	Date -

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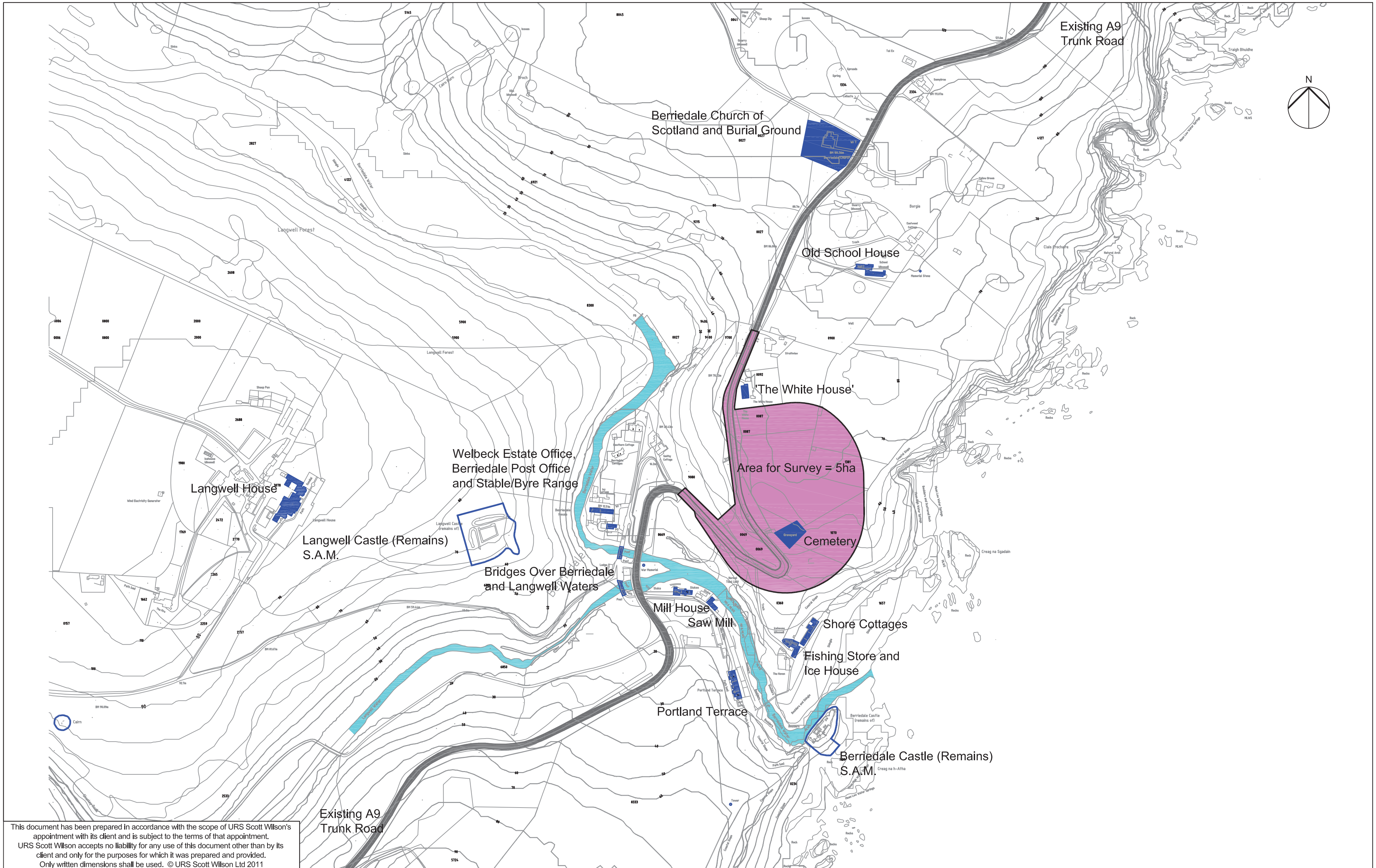

Plot Date :
File Name :

Drawing Title

A9 BERRIEDALE BRAES IMPROVEMENTS
GEOTECHNICAL, DESIGN AND CONSTRUCTION ASSESSMENT

SCOPE OF TOPOGRAPHICAL SURVEY

FIGURE 6

Scale at A3 : 1:5000		
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Chk -	Date 04/05/11	Date -

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