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Field observations and laboratory test results on tills in the Nairn – Inverness area of NE Scotland

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Map

Sheet 84W, Fortrose and Sheet 84E, Nairn, 50 000 scale.

Front cover

View to NNE along the Riereach Burn towards the Moray Firth, showing till sections and glaciofluvial terraces.

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Field observations and laboratory test results on tills in the Nairn – Inverness area of NE Scotland

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) as part of their engineering geological assessment of British tills, being carried out by the Geo-engineering Properties & Processes Team under the BGS Land Use & Development Theme. The tills study forms *Task 1* of the *Physical Properties & Behaviour of UK Rocks & Soils Project*. The report is a factual account of field descriptions and laboratory particle size testing of selected Scottish till sections in the Nairn-Cawdor area, Inverness-shire, Scotland. The work relied heavily on earlier mapping and exposure descriptions undertaken by Clive Auton and Jon Merritt (BGS Murchison House), and on the field leadership of C Auton whose local knowledge of the geology and glacial history of the area was invaluable, as was the morphological sampling experience of Emrys Phillips (also of BGS, Murchison House, Edinburgh).

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Summary

The report describes the field observations, sampling and geotechnical laboratory results on selected Scottish till sections in the Nairn-Cawdor area, Inverness-shire, Scotland. The first part of the report introduces the project and the context of this particular work. This is followed in Part 2 by an account of the sampling and testing methods undertaken for both geotechnical characterisation in the laboratory and micromorphology analyses. Part 3 provides an account of the location details of the logged and sampled exposures and descriptions of the lithological sequences at each site. Part 4 presents details and results of the characterisation tests (particle size analyses) undertaken on the collected geotechnical samples. The results of micromorphological analyses undertaken on thin sections prepared from 'undisturbed' samples acquired from this study are being described in a separate report.

1 Introduction

The work described in this report forms part of a multidisciplinary study of British tills being carried out by the Geo-engineering Properties & Processes Team under the BGS Land Use & Development Theme. The tills study forms *Task 1* of the *Physical Properties & Behaviour of UK Rocks & Soils Project*. The main objective of the project is to develop a better understanding of the engineering geological characteristics and properties of the glacial till deposits across Britain. In addition to acquiring material descriptions and related geotechnical data to aid in the understanding and prediction of their engineering properties and behaviour, the acquired data will add to that already extracted from site investigation reports and entered into the BGS National Geotechnical Properties Database. This database forms the main tool for the attribution of BGS digital geological models and is a prime information source for academic and applied research and internal/external enquiries.

This factual report describes the field observations, sampling and geotechnical laboratory test results undertaken on samples collected from selected Scottish till sections in the Nairn-Cawdor area, Inverness-shire, Scotland.

2 Sample collection and testing

Because of the wide range of particle size distributions (particularly sandy gravels and occasional cobbles) typically found in the dominantly granular till deposits of the study area, undisturbed samples of sufficient size and quality for geotechnical testing could not be easily acquired. Consequently disturbed (bulk) samples were taken to determine particle size gradings. Once taken, the samples were immediately sealed in plastic bags to prevent moisture loss. Sample quantities and laboratory test procedures were undertaken in accordance with British Standard BS 1377:1990 - Methods of test for soils for civil engineering purposes: Parts 1 & 2, respectively.

A detailed composite geological/geotechnical log of the exposures in river cliffs of the Allt Dearg (a north-eastward flowing tributary of the River Nairn) was constructed, but no geotechnical samples were collected at this site. Eight disturbed bulk samples for geotechnical testing were acquired in total; five from two exposure sites in river cliffs of the Riereach Burn and three from an exposure site in a river cliff of the Drynachan Burn (an eastward flowing tributary of the River Findhorn. Sampling and logging locations are given in Figure 1.

In addition to sampling for geotechnical characterisation tests, fifteen ‘undisturbed’ oriented samples were also obtained for subsequent thin section preparation in order to study fine-scale structure (micromorphology) of the sediments (principally of the till units). These samples were taken at specific exposure points at selected localities from all three study areas, using aluminium ‘kubiena’ tins of dimensions 100 x 100 x 100 mm. Samples were acquired by carefully cutting and pushing the kubiena tins into the face of each selected exposure in order to minimise sample disturbance as far as possible. The geographical position, orientation relative to magnetic north, depth and ‘way-up’ of the sample were marked on the outside of each tin following collection. Each sample was then sealed in two plastic bags and stored in a cold store on return to the BGS laboratories to prevent moisture loss. The subsequent preparation of large format orientated thin sections from these kubiena samples requires the initial replacement of pore-water by acetone, followed by progressive replacement by a resin which is then allowed to

cure for c. 10 months to prevent disturbance of fine-scale structure. The microfabric studies undertaken on these samples are being described in a separate report.

3 Field descriptions and sampling locations

3.1 DALCHARN (ALLT DEARG)

Two exposures in river cliffs were described and sampled for micromophology on the southeastern side of the valley of the Allt Dearg, in the vicinity of Dalcharn Cottages; at the Dalcharn East and Dalcharn West localities of Merritt and Auton, 1990 and 1993 (Figure 2). The lithtostratigraphic nomenclature used below follows that of Walker et al. (1992) and Fletcher et al. (1996); the updated equivalent nomenclature for each unit, as given in MacMillan et al. (2011), is shown in Table 1.

3.1.1 Dalcharn West, Site 1 [GR 281445 845217]

The Dalcharn West exposure is located 300 m west of Dalcharn Cottages (Figure 2). The summary lithological description given below (described from top to base) represents a combined log of two contiguous sections identified in Merritt and Auton (1993) as exposures NH84NW E9 [GR 28143 84516] and NH84NW E10 [GR 28146 84521], respectively (Plates 1 to 3).

1. ***Glaciofluvial Deposits (1.5 – 3.0 m)***

Varied glaciofluvial deposits cap the Dalcharn Upper Till. Generally inaccessible for close examination, these mostly stratified deposits include:

1. Orange relatively well sorted, clast-supported, medium-coarse, GRAVEL.

2. Very silty pebbly CLAY.
3 Clayey sandy SILTS.] Mainly light olive-grey (5Y 5/2) mottled dark yellowish orange to dark yellowish brown (1OYR 4/2).

4. Silty SANDS.

2. ***Dalcharn Upper Till Formation (c. 9.5 m)***

Upper Member (3.3 m). Dark yellowish brown (10YR 4/2) massive, matrix-supported generally dense GRAVEL till with a very sandy clay matrix, sand is mainly fine and ultimately loose. Appears less stiff/dense than underlying tills and slightly more clayey. Gravel clasts comprises mainly gneissose semipelite with subordinate psammite, quartzite and red and grey granite. Upper contact with overlying glaciofluvial deposits not easily accessible but appears to be sub-horizontal and planar. Sub-horizontal fissures at 2-30 cm spacing are picked out by Fe/Mn staining or by plastic clay laminae (<5 mm). Rare lenses of clayey fine-medium sand. One distinct lens (1.5 x 0.3 m) of slightly distorted clayey silty sand and gravel observed. Some thin undulating seams of horizontally laminated clayey silt and sand extend over several tens of metres. Sharp horizontal planar contact with underlying lower member of Upper Till. Deposit interpreted as a typical lodgement till.

Lower Member (6.2 m). Strong brown (5YR 4/6) massive, matrix-supported sandy GRAVEL till, very stiff/dense very sandy clay matrix,(sand fine-very fine), ultimately loose. Seems more homogenous than underlying basal till. Gravel clasts comprises mainly gneissose semipelite,

psammite, red granite and fine-medium red-brown sandstone with subordinate grey granite, epidiorite, mica schist and medium-course yellow-brown sandstone and fine flaggy grey-brown sandstone. Sharp horizontal planar contacts both above and below.

3. ***Dalcharn Lower Till Formation (8.5-9.5 m)***

Moderate brown (5YR 4/4) massive to poorly laminated, matrix-supported sandy GRAVEL till, very stiff/dense very sandy clay matrix, (sand fine-very fine), ultimately loose. Seems less homogenous than overlying till. Gravel clasts comprises mainly fine-medium red-brown sandstone, medium-course yellow-brown sandstone and fine flaggy grey-brown sandstone; some gneissose semipelite, psammite and red granite; with subordinate grey granite, epidiorite and mica schist. Sharp horizontal planar contacts both above and below.

4. ***Dalcharn Biogenic Formation*** *(1.3 - 1.6 m)*

Dalcharn Biogenic Member (0.5 – 0.6 m). A compact/dense carbonaceous gravelly sand SILT/clayey SAND resting on the whitened regolith developed on the basal gravels. Deposit about 0.5 m thick (max) but post-depositionally tilted by 40^{o} (306^{o} from north). Charcoal becomes increasingly common upwards until it colours the matrix olive grey (5Y4/1) and light olive grey (5Y 6/1). It is both particulate and finely divided. The unit has a streaked appearance. Some compressed peat. Organic-rich layers (<10 cm) are dusky yellowish brown (10YR 2/2), showing fine but irregular lamination. Some lumps of charcoal up to 50 mm developed, as is some small-scale stratification. Some fine sub-horizontal lamination is present, picked out by clean pale yellowish grey fine sand, together with rare lenses of fine-medium gravel. The lenses are laterally discontinuous, often contorted and generally a few cm thick and up to 0.5 m long. Some 'wisps' of sand are traceable over more than 5m horizontally. Gradational lower boundary. (Plate 2).

Dalcharn Cryurbate Member (0.8 – 1.0 m). Matrix-supported clayey GRAVEL. Matrix comprises a very light grey (N8) clayey (?kaolinitic) silty fine- to very fine-grained sand. Chaotic fabric, no internal stratification. Clasts are similar to those within the underlying gravel, comprising granite, schist and gneiss (many of which are very weak and completely weathered), but yellowish grey coarse sandstone with whitened rinds is predominant, some sandstone clasts are whitened throughout. Clasts are generally very weathered. Charcoal is both disseminated and concentrated into 'streaks'. One boulder of gneiss measured 0.8 x 0.7 x 0.51 m. Up to about l m observed but thicknesses are difficult to judge due to post depositional forward tilting. Locally the deposit has a sharp base, which is best developed where the matrix is most clayey, but elsewhere its basal contact is gradational over 30cm.

4. ***Dalcharn Gravel Formation (c. 3.0 m)***

In general a poorly sorted, extremely consolidated COBBLE-GRAVEL with boulders up to 350mm quite common. Generally clast-supported, albeit matrix rich, but there are some minor beds with matrix-support. Fabric is apparently chaotic but some very subtle sub-horizontal stratification is poorly preserved. Several distinct beds are recognised (see Merritt and Auton,1993 for detailed description). Gravel clasts comprise mainly gneissose semipelite with additional quartzite, epidiorite, mica schist, grey and red granite, fine-grained pale grey and coarse-grained red-brown sandstone, and subordinate gabbro, pegmatite and conglomerate.

Sampling

- No geotechnical samples taken.
- **Kubiena tin sample No. 1** taken for thin section fabric studies at GR 28144 84528, in sandstone-rich Dalcharn Lower Till (Plate 2).

Lithostratigraphical Unit (Walker et al, 1992)	MacMillan et al, 2011
Glaciofluvial Deposits	Equivalent to the **CARN MONADH GRAVEL FORMATION** of the Central Grampian Glacigenic Subgroup
Dalcharn Upper Till Formation	**BEINN AN UAIN TILL FORMATION** of the Central Grampian Glacigenic Subgroup
Dalcharn Lower Till Formation	**ATHAIS TILL FORMATION**
Dalcharn Biogenic Formation	**DALCHARN PALAEOSOL FORMATION**
Dalcharn Gravel Formation	**CRAIG AN DAIMH GRAVEL FORMATION**
Dearg Till Formation	**SUIDHEIG TILL FORMATION**

Table 1. Revised lithostratigraphy of the Dalcharn Site.

3.1.2 Dalcharn East, Site 2 [GR 281570 845371]

The Dalcharn East exposure is located in the Allt Dearg stream section, 430 m northwest of Dalcharn Cottages (Figure 2). The lithological description given below (described from top to base) represent a summary of that presented by Merritt and Auton (1993) for their exposure NH84NW E11 [GR 281570 845370] (Figures 4 to 6).

1. ***Glaciofluvial Gravel (1.9 m).***

Course GRAVEL to COBBLES with clasts comprising psammite, semipelite, quartzite, red & grey granite. Dense-packed beds (<30 cm) showing good imbrication dipping upstream. Sharp erosional base (Plate 4).

2. ***Dalcharn Upper Till Formation (c. 3.7 m)***

Upper Member (1.1 m). Moderate to dark yellowish brown (10YR 4/3) sandy GRAVEL till with very stiff/dense clayey silty fine sand matrix. Scattered clasts <400 mm, comprising psammite, semipelite, quartzite, brown & grey fine-sandstone and pink porphyry. Poor fabric. Some sub-horizontal closely spaced fissures, especially towards top. Unit is pinched-out upstream. Planar, sub-horizontal sharp base. [Lodgement till].

Lower Member (2.6 m).

1.5 m Bed 1: Moderate yellowish brown (10YR 5/4) clayey fine-coarse sand matrix, more loose than above but still very stiff/dense. Clasts as above, some prominent red granite and scratched, flat-iron boulders of grey-brown fine sandstone.Several discontinuities, gently concave, dipping downstream with some alignment of clasts along them. Sharp, sub-horizontal, planar base. [Classic lodgement till].

<0.4 m Bed 2: very stiff/dense clayey silty fine sand matrix matrix as in Upper Till Formation but dark yellowish brown (10YR 4/2); pinches out upstream. Sharp, sub-horizontal, planar base.

0.7 m Bed 3: matrix as top bed of Lower Member but moderate yellowish brown (10YR 5/4). Sharp, sub-horizontal, planar base on large scale but gentle undulations on small scale. Pull-apart structures and fissures penetrating the underlying till. Rare streaks of underlying till at base. [Lodgement till].

3. ***Dalcharn Lower Till Formation (c. 11.1 m)***

3m Bed 1: Moderate brown (5YR 4/4) with reddish tint very stiff very sandy clay matrix. Many scratched cobbles & boulders of sandstone and flagstone. One large pull-apart structure at top, 0.8 m by 0.4 m, filled with clast-supported gravel and clayey sand. Some sub-horizontal (5-15 mm) anastomising fissures towards the top filled with fining upwards seams of sand/silt (10 YR 5/4). Other penetration fissures concave upwards, dipping downstream. Rare rip-up clast (100 mm) of lower unit towards base. Gradational contact with underlying unit (over a distance of 0.4m). [Lodgement till].

3.l m Bed 2: Moderate yellowish brown (10YR 5/4) interbedded clayey sand and gravel. The unit includes clean sands, granule gravel, some sandy clay, wispy beds and laminae of fine sand and silt. There are several thicker and more laterally persistent beds of clean fine to medium sand, some graded beds of sand and silt with minor cross-lamination, and some laminae of reddish-brown plastic clay. Clasts are generally <200 m, including tabular flat-lying cobbles. Beds generally 5-15 mm thick, impersistent over approximately a metre or so; many have winnowed tops. Not overconsolidated. In the east of the section a lens of fine sand and gravel about 0.5m from base reaches l m in thickness. The lens comprises fine-medium sand with rare impersistent laminae of yellow-brown clay, a 20 mm thick seam of reddish brown plastic clay is present at its base. Overlain by 0.2 m of clayey clast-supported gravel. Gradational base. [Flow till/Meltout till complex?].

4-5m Bed 3: Moderate yellowish brown (10YR 5/4) sandy clay to clayey sand matrix, with minor wisps of fine sand and silt. In part a sand and gravel.; not over consolidated, fairly loose but stiffer where more clayey. Clasts <300 mm. Quite dense overall, but more clayey towards sharp base.

4. ***Dalcharn Gravel Formation (c. 2 m)***

Dense clast supported and very poorly sorted matrix-rich COBBLE-GRAVEL. No stratification observed. Good fabric indicating palaeocurrent towards the north east. Matrix comprises dark yellowish brown (10YR 4/2) silty fine-coarse SAND. Clasts (<400 mm) comprise red granite, pelite, semipelite gneiss and slabs of grey-brown flagstone. Many clasts, especially the pelites and semipelites, have orange weathering rinds, some clasts are completely decomposed. Many granites look fresh but are actually quite weathered and easily disintegrate under the hammer. Some flagstones are very weak and completely weathered. In general, the gravel becomes less weathered downwards. Several infiltration cracks exposed penetrating gravel formation, dipping at approx. 40^{o} (90^{o}-100^{o} from north) and infilled with parallel laminated fine-medium sand or moderate yellowish brown clay. Infills include some graded units. Sharp, undulating erosional base.

5. ***Dearg Till Formation (1.0 m +)***

Moderate yellowish brown (10YR 5/4) to moderate brown (5YR 3/4) very stiff fine sandy silty clay matrix, with scattered gravel, cobble and boulder-sized (>200 mm) clasts. Clasts (<0.4 m) are generally fresh except pelitic mica schist, some semipelitic gneiss and grey granite. The largest clasts are of olive grey flagstone. Structureless apart from subhorizontal and near vertical fissuring (Plate 6).

Sampling

- No geotechnical samples taken.

- **Kubiena tin sample No. 2** taken for thin section fabric studies at GR 281570 845370, in Dalcharn Lower Till Formation ('Middle member', 'Bed 2' – sandstone-rich meltout till).

3.2 RIEREACH BURN

Four exposures were described and sampled in the Riereach Burn stream section (Figure 3). The first location at GR 283903 843170 is identified and described by Merritt and Auton (1993) as exposure NH84SW E17 (Location CA4133). The second and third exposures are 'new' sections located at GR 284530 844132, GR 84479 844052 and GR 284605 844123, some 1.14, 1.0 and 1.18 km downstream (NNE) of exposure E17, respectively.

3.2.1 Riereach Burn Site 1 [GR 283903 843170

This site corresponds to Section NH84SW E17, Location CA4133, in Merritt and Auton (1993), upon which the following description of the lithologies present is based (Plates 7 to 11):

c 8.0 m Moderate brown (5YR 3/4) to reddish grey (5YR 5/2) very dense SAND with abundant sandstone gravel, cobble and boulders. Clasts are dominantly well rounded Old Red Sandstone (>40%) up to 0.5m diameter; subangular psammite, and pink and white granite. A few sand wisps are present near the base. [Sandy lodgement till] (Plate 7; Plate 8). This unit probably equates with the Finglack Till Formation of MacMillan et. al (2011).

0.3 m Boulder lag in a matrix of coarse angular sand composed of lithic grains, quartz and feldspar. Large subangular and angular tabular blocks of green sandstone. Sheared basal contact with underlying till. The deposit marks the position of a perched water table above the less permeable till below; the latter, in places shows orange Fe staining on exposed surfaces from percolating waters (Plate 7; Plate 8).

1.0 m+ Brownish grey (5YR 4/11 or greyish brown (2.5YR 5/2) to olive grey (5Y 4/1) very dense slightly gravelly fine to coarse SAND, with abundant rounded clasts (up to 300 mm) of psammite, and dark grey sandstone and some angular clasts of white granite. Gravel is fine to coarse subangular to rounded (2 – 50 mm) (Plate 9; Plate 10; Plate 11). This unit is probably a pre Late Devnsian Till of the Central Grampian Galcigenic Subgroup (MacMillan et. al., 2011). It occurs at the base of the till sequence in the Riereach Burn area (see Figure 26b of Fletcher et. al. 1996) and is probably of comparable age (MIS ?3) to the Ardverikie Till Formation of the Gaick Plateau. It differs from the former, however, in containing a high proportion of rounded (occasionally polished) clasts of grey psammite.

Sampling

- **Geotechnical sample Riereach Burn Site 1: No. 1 (129/1)** taken at GR 283905 843185 in basal brown-grey psammite/granite-rich till.
  Geotechnical sample Riereach Burn Site 1: No. 2 (129/2) taken at GR 283908 843153 in upper reddish grey/moderate brown sandy lodgement till.

- **Kubiena tin samples No. 3 & 4** taken for thin section fabric studies at GR 283903 843151, in basal brown-grey psammite/granite-rich till.

3.2.2 Riereach Burn Site 2 [GR 284531 844127]

This site is a new section on the eastern side of the Rierach Burn (CA4134), previously not described (Plates 12 and 13)

c. 1.5-2.0 m Fluvioglacial (?channel) deposits comprising SAND rounded to sub-rounded coarse GRAVEL and COBBLES and occasional BOULDERS becoming more sandy towards base. Fairly sharp, slightly undulating basal contact (Plate 12).

c. 0.8-1.0 m Interbedded fine – medium to coarse – gravelly SAND, beds becoming more gravelly at base. Laminated clayey SILT band with sand stringers or folded sand beds occurs near base of dominantly sand sequence above sharp contact with lower till. [Channel infill] (Plate 12).

c. 2.0+ m Dense to very dense brown (7.5YR 5/4) slightly silty, cobbley, gravelly fine to course SAND. Gravel is fine to coarse (2-60 mm) with clasts mainly of sandstone and granite. [Basal till; possible equivalent to Dalcharn Lower Till] (Plate 13).

Sampling

- **Geotechnical sample Riereach Burn Site 2: No. 1 (129/3)** taken at GR 284531 844127 in basal cobbley, gravelly, sandy till.
  Geotechnical sample Riereach Burn Site 2: No. 2 (129/4) taken at GR 284524 844136 in basal cobbley, gravelly, sandy till.
- **Kubiena tin samples Nos. 5 & 6** taken for thin section fabric studies at GR 284530 844132 in laminated clayey silt with folded bed of fine sand/ clay stringers.
  Kubiena tin sample No. 7 taken for thin section fabric studies at GR 284530 844132 in basal till; possible equivalent to Dalcharn Lower Till.

3.2.3 Riereach Burn Site 3 [GR 284479 844052]

This is a new section (CA4136) on the western bank of the Rierach Burn, previously not described (Plates 14 and 15)

0.8-1.0 m River terrace deposits comprising gravelly, cobbley SAND and frequent boulders (>200 mm). Clasts are well rounded to angular comprising psammite, granite and sandstone. Sharp approximately planar contact with underlying till (Plate 14).

2.5+ m Brown (10YR 5/3) dense to very dense slightly silty very gravelly fine to medium sand with frequent cobbles and boulders. Gravel comprises fine to coarse sub-angular to rounded sandstone, granite, gneiss, quartzite and psammite. [Probable equivalent to Dalcharn Lower Till] (Plate 14 ;Plate 15).

Sampling

- **Geotechnical sample Riereach Burn Site 3: No. 1 (129/5)** taken at GR 284479 844502 in basal cobbley, gravelly, sandy till.
- **Kubiena tin sample No. 12** taken for thin section fabric studies at GR 284503 844042 in basal sandstone-rich till. Probable equivalent to Dalcharn Lower Till?

3.2.4 Rierach Burn Site 4 [GR 284605 844123]

This is a new section (CA4135) on the western bank of the Rierach Burn, previously not described (Plates 16 to 20).

8-10+ m exposure. (Figure 4)

c. 2-3 m Orange brown fine to medium SAND with sharp sub-horizontal basal contact marked by Fe oxide staining with underlying gravel. Steeply dipping (c 40^{o}-60^{o}) fractures (hydrofractures) filled with fine sand and silt cut sand sequence and continue into underlying gravels. (Figure 4; Plate 16; Plate 17).

c. 6-7+ m Dense mainly highly weathered/decomposed sandy fine to coarse GRAVEL with frequent highly weathered cobbles, although not all clasts are weathered to same degree. Gravel and cobble clasts are sub-rounded to rounded. Steeply dipping (c 40^{o}-60^{o}) fractures (hydrofractures) filled with banded fine sand, silt and brown clay cut the gravel sequence and continue into overlying sands. In places, infilled fractures cut gravels but terminate at basal sand contact. A sub-horizontal 50-100 mm thick layer of yellowish brown (10YR 6/4) very dense silty fine–medium sand occurs within the gravel sequence c. 2 m from base of exposure and shows no shear displacement where cut by hydrofractures. At one location a steeply-inclined silt/sand-lined fracture is refracted by the lower sand layer (Plate 19). The same silt/sand-lined fracture is also seen to cut a decomposed psammite cobble with no shear displacement being evident (Plate 20).

Note that the weathered/decomposed gravel sequence may be equivalent to a thicker development of gravel comparable to part of the Dalcharn Gravel Formation, although in this instance, there is no biostratgraphical control (as there is at Dalcharn) to confirm an interglacial origin for this unit.

Sampling

- No geotechnical samples.
- **Kubiena tin samples Nos. 8 to 11** taken for thin section fabric studies at GR 284605 844123.
  Kubiena tin sample No. 8 in orange sand/silt vein cutting sand bed.

  Kubiena tin sample No. 9 in orange sand/silt vein cutting clayey silt overlying weathered gravel.

  Kubiena tin sample No. 10 in graded laminated silty clay and sand in high-angle sand vein at southern end of section.

  Kubiena tin sample No. 11 in vein of orange sand/silt cutting deeply decomposed clast of micaceous psammite.

3.3 DRYNACHAN BURN

Two closely adjacent sections were examined and sampled at Drynachan Byrn West (CA4137) [GR 285987 839975] and East (CA4138) [GR 286035 839963] sections, respectively (Figure 5). The sections are equivalent to the identified exposure Drynachan Burn, E1, in Merritt and Auton (1993).The summary lithological description given below (described from top to base) represents a combined log of the two sections (Plates 21 to 25).

c.1.0+ m Upper strongly laminated dark greyish brown (10YR 4/2) very stiff slightly gravelly sandy SILT with wisps of sand and clay-lined shears. Gravel clasts are medium to coarse sub-rounded to angular psammite and grey and pink granite, flint. [Stratified flow till?] (Plate 25)

3.5 m Dark greyish brown (10YR 4/2) to light olive brown (2.5Y 5/4) compact/very stiff SILT sometimes interbedded with 10 – 30 mm thick beds of laminated (laminations 5 mm-20 mm) medium to coarse sand. Occasional gravel, medium to coarse, of psammite, gneiss and sandstone. Rare cobbles. Irregular gradational base. [Lodgment Till].

2.0 m Dark greyish brown, compact/stiff clayey SILT with wisps and discontinuous lenses of very pale orange (10YR 8/2) fine clean quartz sand.

0.3+ m Interbedded fine sand and silty clay.

Note that all of the till units are comparable lithologically with those exposed in the upper parts of the Dalcharn sections, [Dalcharn Upper Till Formation] although laminated and stratified units are generally not present in the Formation in those exposures.

Sampling

- **Geotechnical sample Drynachan Burn Site 1 (West): No. 1 (129/6)** taken at GR 285987 839975 in silty grey brown/light olive brown lodgement till.
  Geotechnical sample Drynachan Burn Site 1 (West): No. 2 (129/7) taken at GR 285988 839969 in silty grey brown/light olive brown lodgement till.

  Geotechnical sample Drynachan Burn Site 2 (East): No. 1 (129/7) taken at GR 286035 839963 in compact light olive brown occasionally gravely, sandy SILT.

- **Kubiena tin sample No. 13** taken for thin section fabric studies at GR 285990 839974 in grey-brown psammite-rich till, possible equivalent to Dalcharn Upper Till (Upper sample).
  Kubiena tin sample No. 14 taken for thin section fabric studies at GR 285990 839974 in brown stratified, laminated psammite-rich till, almost stone-free, possible equivalent to Dalcharn Upper Till, lower sample(Plate 22).

  Kubiena tin sample No. 15 taken for thin section fabric studies at GR 286027 839902 in lens of laminated silty sand below upper grey-brown stratified psammite-rich till, possibly equivalent to Dalcharn Upper Till (Plate 23).

3.4 SUMMARY OF COLLECTED GEOTECHNICAL SAMPLES

A summary of the geotechnical samples collected for particle size analyses is shown in Table 2.

Table 2 Summary details of geotechnical samples

Laboratory Number	Location	Site Sample No	Easting	Northing	Description
129/1	Riereach Burn Site1	1	283905	843185	Very dense greyish brown (2.5Y5/2) slightly clayey gravelly fine to coarse SAND. Gravel is fine to coarse subangular to rounded (2 mm-50 mm). Occasional boulder up to 300 mm sandstone, granite and psammite. Bottom till grey.
129/2	Riereach Burn Site 1	2	283908	843153	Very dense reddish grey (5YR5/2) slightly clayey gravelly fine to coarse SAND. Gravel is fine to coarse subangular to rounded of sandstone, granite and psammite. Occasional boulder up to 300 mm.
129/3	Riereach Burn Site 2	1	284531	844127	Dense, cobbley, silty gravelly SAND
129/4	Riereach Burn Site 2	2	284524	844136	Very dense, silty, cobbley, very gravelly SAND
129/5	Riereach Burn Site 3	1	284479	844052	Dense to very dense brown (10YR5/3) slightly silty very gravelly fine to medium SAND with occasional cobbles and boulders. Gravel is fine to course subangular to rounded sandstone, granite, gneiss, quartzite and psammite.
129/6	Drynachan Burn Site 1	1	285987	839975	Compact light olive brown (2.5Y5/4) SILT interbedded with 10 -30mm thick beds of laminated (laminations 5 - 20 mm) medium to coarse SAND and fine to coarse gravel of psammite, gneiss and sandstone. Very occasional cobbles.
129/7	Drynachan Burn Site 1	2	285988	839977	Compact light olive brown (2.5Y5/4) SILT interbedded with 10 -30mm thick beds of laminated (laminations 5 - 20 mm) medium to coarse SAND and occasional medium to coarse gravel of psammite, gneiss and sandstone. Very occasional cobbles.
129/8	Drynachan Burn Site 2	1	286035	839963	Compact light olive brown (2.5Y5/4) gravelly, sandy SILT. Gravel is fine to coarse.

4 Laboratory test results

4.1 TEST METHODS AND PROCEDURES

Geotechnical laboratory testing entailed the determination of particle size gradings on the disturbed (bulk) samples collected from the granular tills at the Riereach Burn and Drynachan Burn exposures. Both coarse and fine grained particle size test procedures were undertaken.

Coarse grain particle size analysis was carried out using the wet sieving method described in British Standard BS 1377: Part 2: 1990, test 9.2 supplemented by the recommendations given in Head (2006). A sieve spacing of 0.5 ϕ was used for sand size particles (0.063 mm to 2 mm) and a1ϕ sieve spacing for gravel size particles (2 mm to 63 mm). The data does not include particles larger than gravel size (>63 mm) as this size fraction could not be correctly represented from the size of the acquired field sample. The sample and exposure descriptions provide guidance to the proportion of coarser particles.

For fine grained particle size analyses a 5 g oven-dried sub-sample was selected from the <0.063 mm (silt and clay) washings of the whole sample. This was then mixed with a 0.05% solution of sodium hexametaphosphate disaggregant to form a suspension. The suspension was transferred to an X-ray Sedigraph particle size analyser and the automated computer-controlled system started. The sub-sample particle size values were then integrated with the coarse analysis to obtain a full grading curve. The X-ray Sedigraph system was calibrated with a garnet standard prior to testing.

4.2 RESULTS

The results of the particle size analyses are summarised in Table 3 and as grading curves (Figures 6 and 7). Detailed test data for individual test samples are presented in Appendix 1.

Table 3 Summary particle size data

Site	Sample	Laboratory Sample	Particle Size %			
			Clay	Silt	Sand	Gravel
Riereach Burn 1	1	129/1	11.8	11.5	49.5	28.7
Riereach Burn 1	2	129/2	5.9	8.7	48.7	36.6
Riereach Burn 2	1	129/3	6.9	15.4	42.8	34.9
Riereach Burn 2	2	129/4	11.7	9.7	55.5	23.1
Riereach Burn 3	1	129/5	13.5	15.8	49.7	21.0
Drynachan Burn Section 1	1	129/6	3.3	36.9	49.5	10.3
Drynachan Burn Section 1	2	129/7	4.3	39.1	55.5	21.8
Drynachan Burn Section 2	1	129/8	12.1	17.8	49.7	20.3

Glossary

Clast – Individual single piece of detrital material derived from a sedimentary, igneous or metamorphic rock, usually referring to material of gravel size (>2 mm) or greater.

Clast- supported – Describes a fragmentary deposit where all the detrital grains are in contact.

Grain - Individual single piece of detrital material derived from a sedimentary, igneous or metamorphic rock, usually referring to sand size (0.063 to 2.0 mm) or silt size (0.063 to 0.002 mm) material.

Grain size – (a) clay < 0.002 mm (2 microns) in size; (b) silt, 0.002 to 0.063 mm in size; (c) fine sand, 0.063 to 0.20 mm in size; (d) medium sand, 0.20 to 0.63 mm in size; (e) coarse sand, 0.63 to 2.0 mm in size; (f) fine gravel 2.0 to 6.3 mm in size; (g) medium gravel 6.3 to 20 mm in size; (h) coarse gravel 20 to 63 mm in size; (i) cobbles 63 to 200 mm in size; (j) boulders >200 mm.

Matrix-supported – Describes a fragmentary deposit where the detrital grains are, to varying degrees, isolated/supported within a finer grained matrix.

Matrix – Material, usually clay minerals or micas, forming a bonding substance to grains in a clastic sedimentary rock. The matrix material was deposited with the other grains or developed authogenically by diagenesis or slight metamorphism. Also used more generally for finer grained material in any rock in which large components are set.

MIS.– Marine Isotope Stage (abbreviation for a chronostratigraphical subdivison of the Quaternary based on oxygen isotopes)

Micromorphology – A term used to describe the study of unlithified glacial sediments in thin section using a petrological microscope.

Rounded – Describes the smoothness of the surface of a grain. The terms well-rounded, rounded, subrounded, subangular, angular, very angular are used to describe the increasingly angular/irregular/rough nature of the surface of detrital grains.

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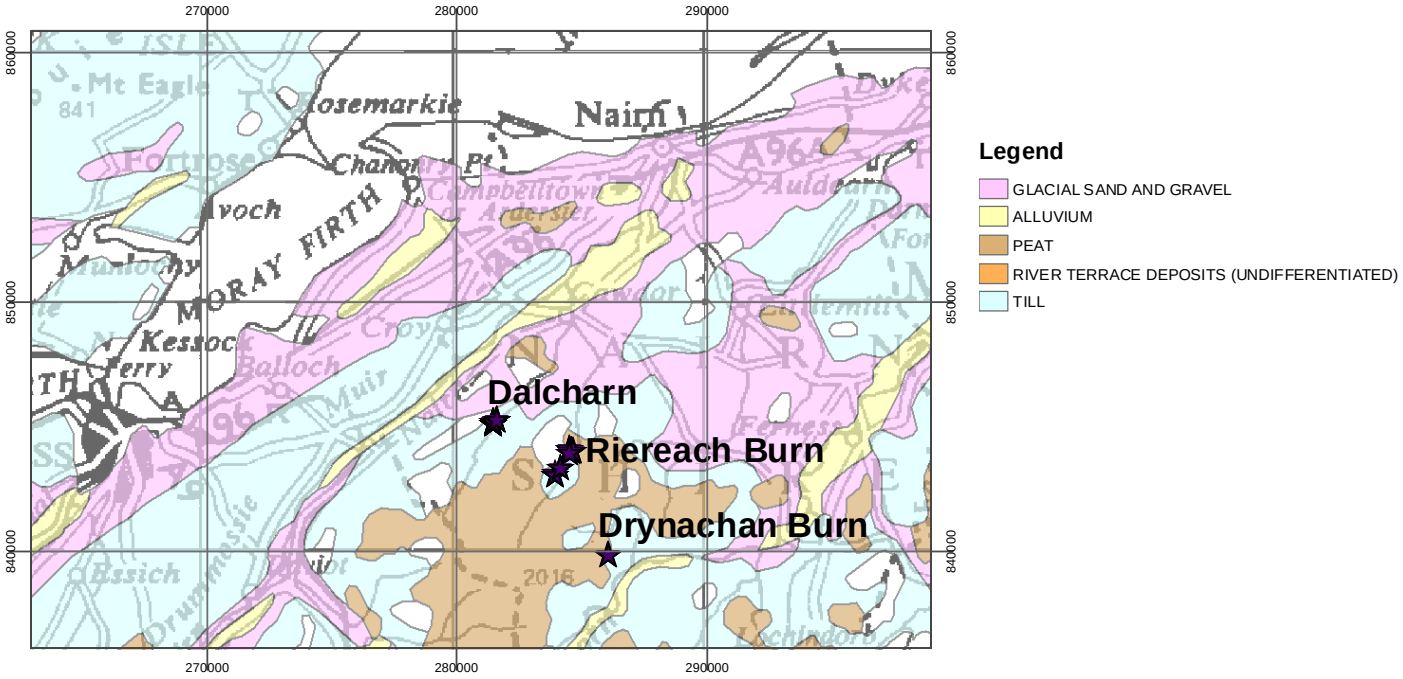


Figure 1 General location of till study sites in the Nairn-Cawdor area, Inverness-shire

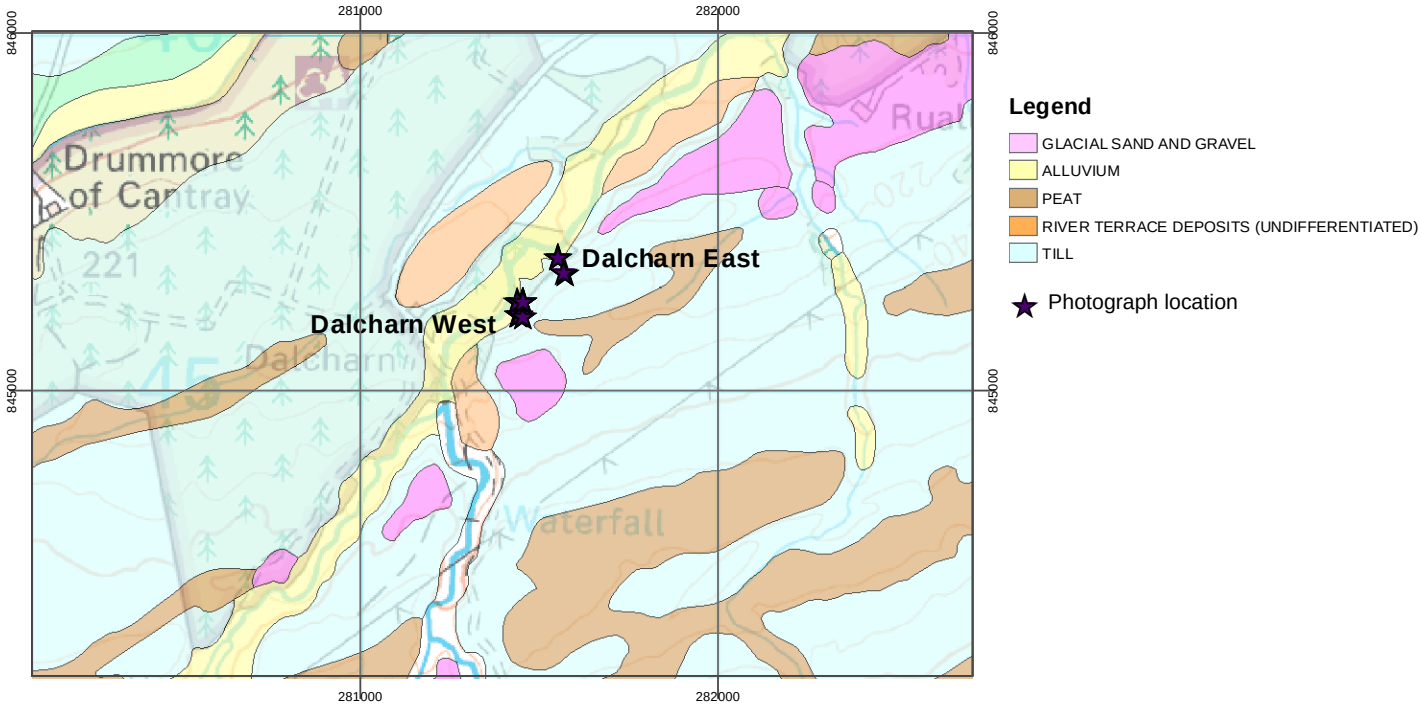


Figure 2 Allt Dearg stream, location of Dalcharn East and Dalcharn West study sites.

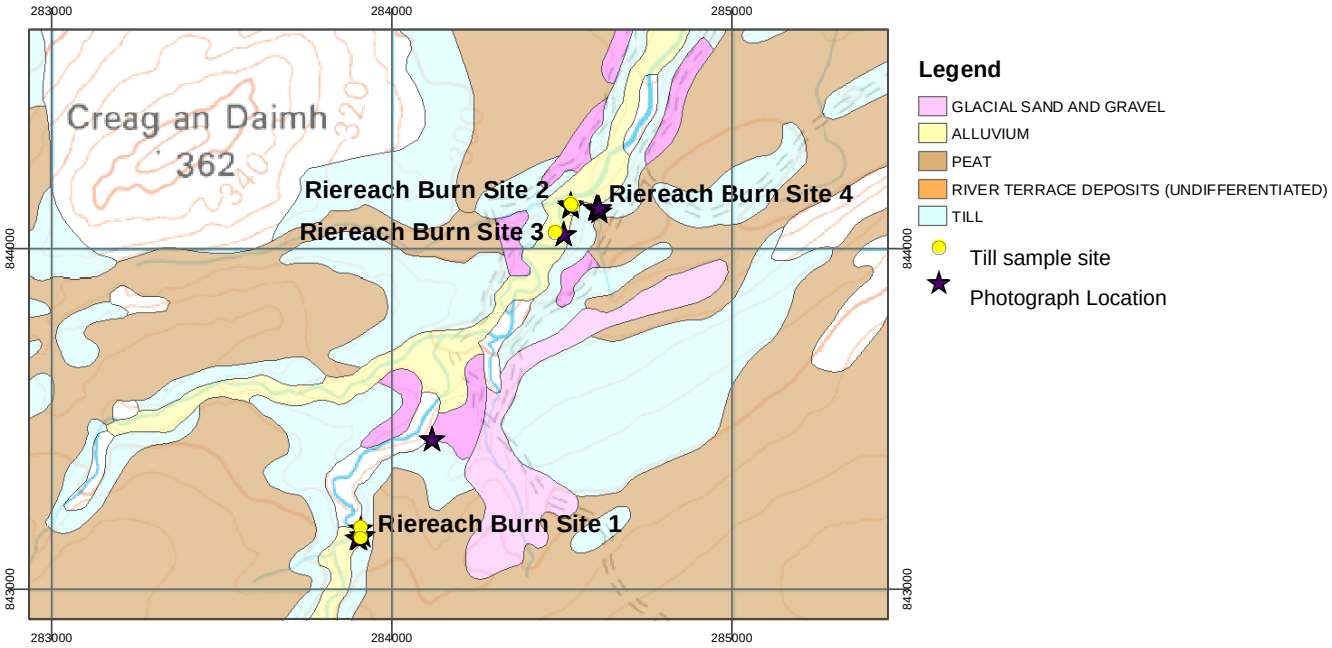


Figure 3 Riereach Burn, location of study sites No.s 1-4.

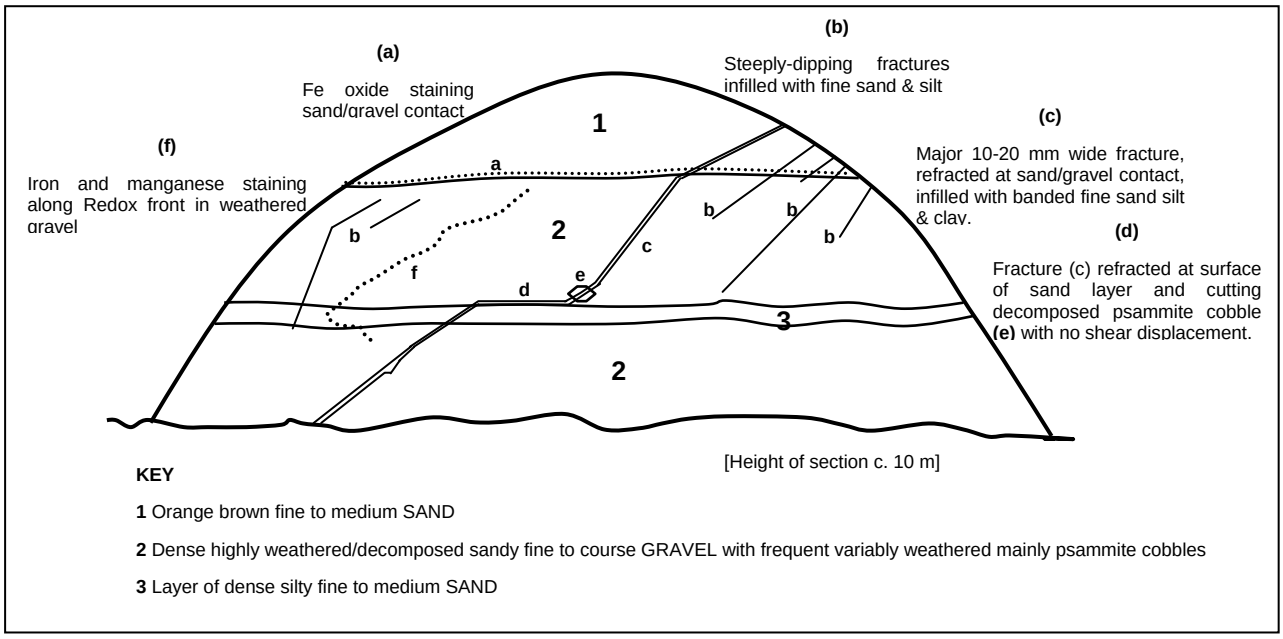


Figure 4 Diagram of exposure at Riereach Burn Site 4 showing lithological relationships, fracture (?hydrofracture) sets and weathering fronts.

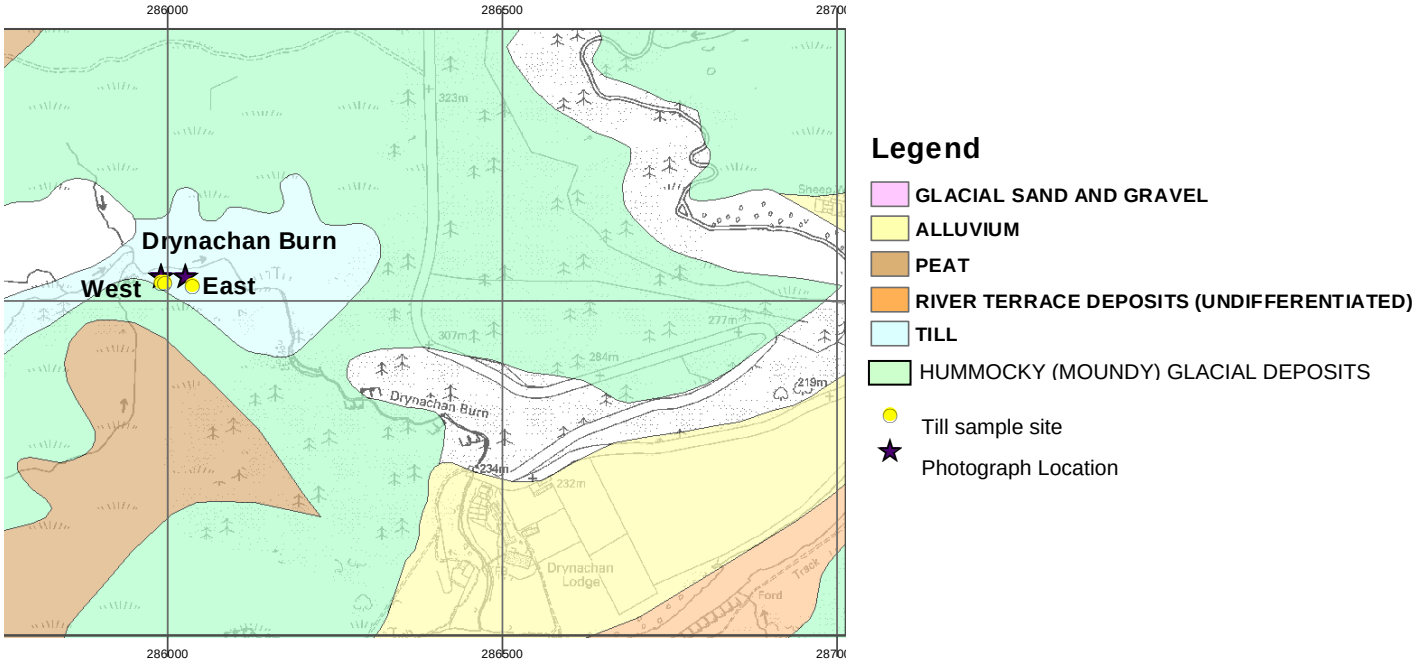


Figure 5 Drynachan Burn, location of East and West study sites.

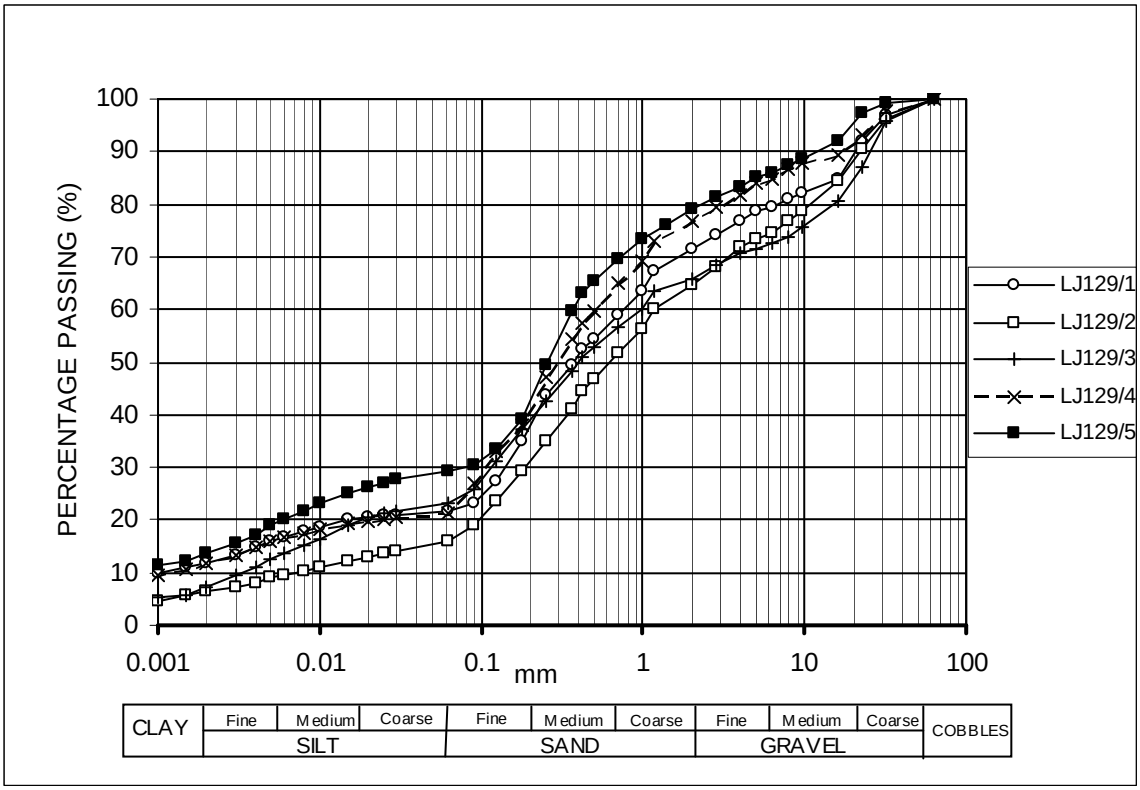


Figure 6 Particle size distribution graph for samples from Riereach Burn sites 1, 2 and 3

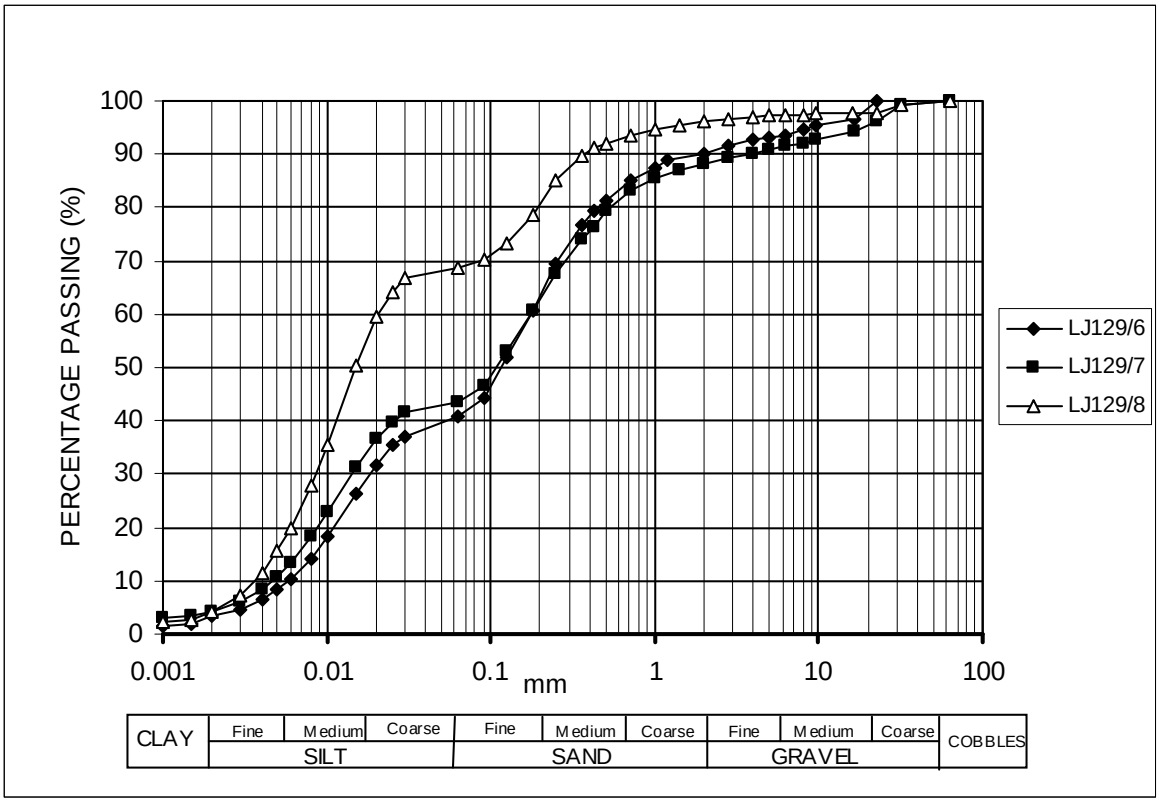


Figure 7 Particle size distribution graphs for samples from Drynachan Burn sites 1 and 2.

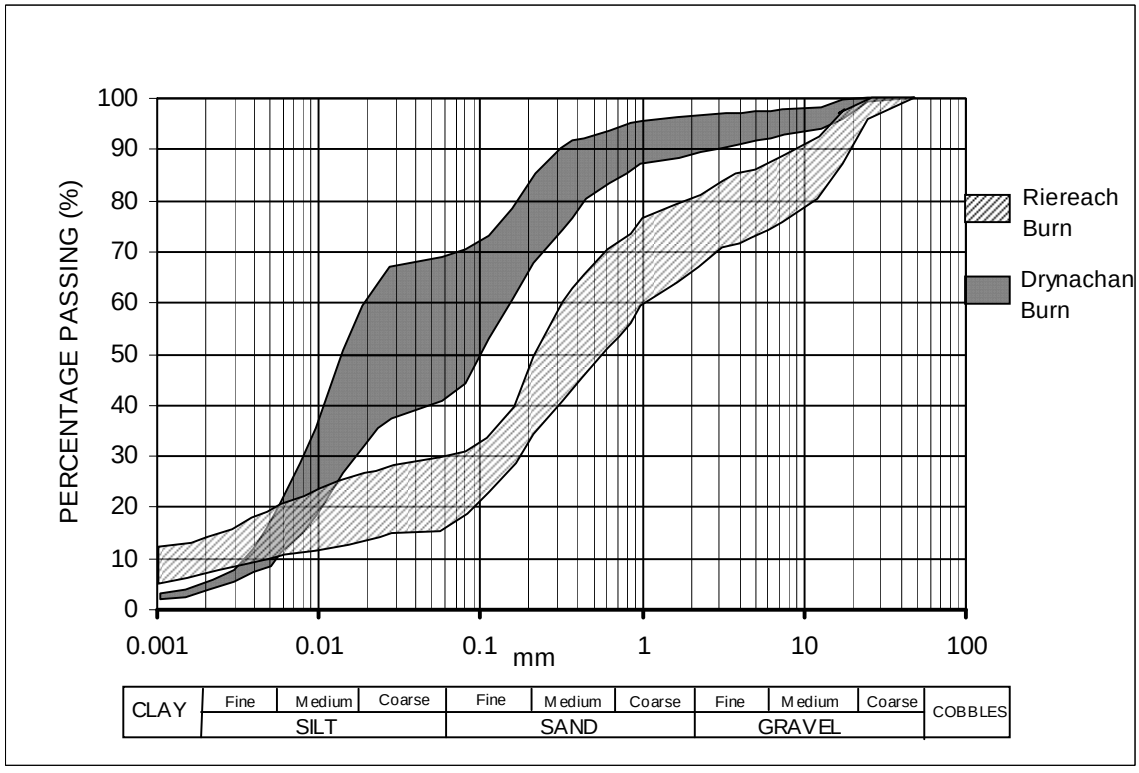


Figure 8 Summary particle size distribution envelopes for the Riereach Burn and Drynachan Burn sites.

Plate 1 Dalcharn West, Site 1, Section NH84NW E9/E10, Allt Dearg stream. [GR 281445 845217]

Plate 2. Dalcharn West, Site 1, Section NH84NW E9/E10, Allt Dearg stream. [GR 281445 845217]

Plate 3 Dalcharn West, Site 1, Section NH84NW E9/E10. Close up of kubiena tin sample location in sandstone-rich Dalcharn Lower Till. Scale 10 cm.[GR 281445 845217]

Plate 4 Dalcharn East, Site 2, Section NH84NW E11, Allt Dearg stream. View looking northwest. [GR 281552 845374]

Plate 6 Dalcharn East, Site 2, Section NH84NW E11, Allt Dearg stream. View looking north. Note shear plane(s) marked by trowel and 15 cm scale in ?Dearg Till Formation near base of section [GR 281570 845331]

Plate 5 Dalcharn East, Site 2, Section NH84NW E11, Allt Dearg stream. View looking north-northwest showing lower part of till sequence. [GR 281570 845331]

Plate 7 Riereach Burn Site 1, Section NH84SW E17. View to northeast showing part of exposure. [GR 283905 843185]

Plate 8 Riereach Burn Site 1, Section NH84SW E17. Boulder lag deposit in a matrix of coarse sand with a sheared basal contact with underlying brown-grey till. The lag deposit gives rise to a perched water table, marked by orange Fe staining on exposed surface of underlying till. [GR 283905 843185]

Plate 9 Riereach Burn Site 1, Section NH84SW E17. Close-up of grey-brown basal granite/psammite-rich subglacial till.

Plate 10 Riereach Burn Site 1, Section NH84SW E17. Micromorphology sampling of grey-brown basal granite/psammite-rich suglacial till. Kubiena sample tin 10cm x 10 cm. (Sample 3).

Plate 11 Riereach Burn Site 1, Section NH84SW E17. Micromorphology and geotechnical sampling of grey-brown basal granite/psammite-rich suglacial till at Riereach Burn Section E17. Kubiena sample tin 10cm X 10 cm. (Sample 3); Geotechnical sample RB1 (129/1). [GR 283905 843185]

Plate 12 Riereach Burn Site 2. Sandy fluvioglacial (channel) deposits with laminated clayey silt bands overlying very dense basal cobbley, gravelly sandy till. Contact at position of 10 cm scale. [GR 284531 844127]

Plate 14 Riereach Burn Site 3. Exposure of sandstone-rich subglacial till exposed beneath river terrace on western bank of Rierach Burn. [GR 284479 844052]

Plate 13 Riereach Burn Site 2. Close-up of very dense basal cobbley, gravely, sandy till. Scale 10 cm. [GR 284531 844127]

Plate 15 Riereach Burn Site 3. Close-up of water-washed exposure of sandstone-rich subglacial till exposed beneath river terrace. Hammer c 34 cm. [GR 284479 844052]

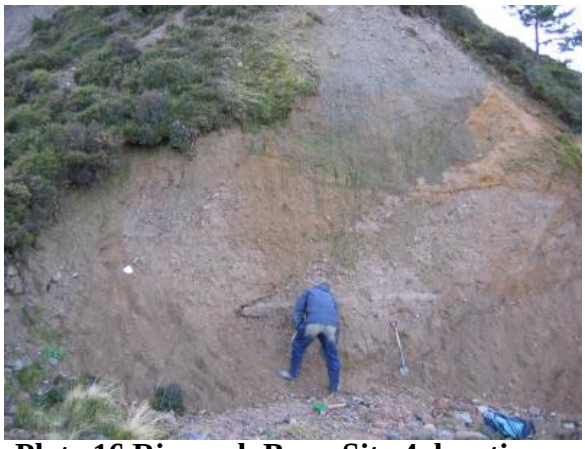


Plate 16 Riereach Burn Site 4, location CA4135. Cleaning the exposure. The gravel and the overlying orange sandy silt are cut by inclined fractures lined with graded laminated orange silt and sand. [GR 284605 844123]

Plate 17 Riereach Burn Site 4, location CA4135. Final cleaned exposure.

Plate 18 Riereach Burn Site 4, location CA4135. Iron and manganese staining along Redox front developed in deeply decomposed gravel. Trowel 17 cm long. [GR 284605, 844123]

Plate 19 Riereach Burn Site 4, location CA4135. Close up of deeply decomposed gravel with thin interbed of sand. The steeply inclined silt-lined fractures are refracted by the sand bed.Trowel 17 cm. [GR 284605, 844123]

Plate 20 Riereach Burn Site 4, location CA4135. Decomposed psammite cobble cut by fracture filled with orange silt and sand within deeply decomposed gravel. Scale 10 cm. [GR 284605, 844123]

Plate 21 Drynachan Burn Site 1 (West Section), equivalent to Section NH83NE E1. Sampling in silty grey brown/light olive brown lodgement till. [GR 285987 839975]

Plate 22 Drynachan Burn Site 1 (West Section), equivalent to Section NH83NE E1. Position of micromorphology Sample 14, from laminated almost pebble-free till. Trowel 17cm long. [GR 285990, 9839974]

Plate 23 Drynachan Burn Site 1 (West Section), equivalent to Section NH83NE E1. Position of Micromorphology Sample 15, from lens of laminated silt below upper strongly laminated till.

Plate 24 Drynachan Burn Site 1 (West Section), equivalent to Section NH83NE E1. Close up of silty grey brown/light olive brown lodgement till. Holes indicate points of 'Wenner Array' resistivity measurements[GR 285987 839975]

Plate 25 Drynachan Burn Site 2 (East Section), equivalent to Section NH83NE E1. Upper strongly laminated, very stiff slightly gravely, silty till. Scale 10cm long. [GR 286030, 839900]

Appendix 1

Detailed test data and particle size distribution graphs are presented here for each of the Riereach Burn and Drynachan Burn samples tested.

RIEREACH BURN SITE 1, SAMPLE NO. 1 (129/1) [GR 28598 839975]

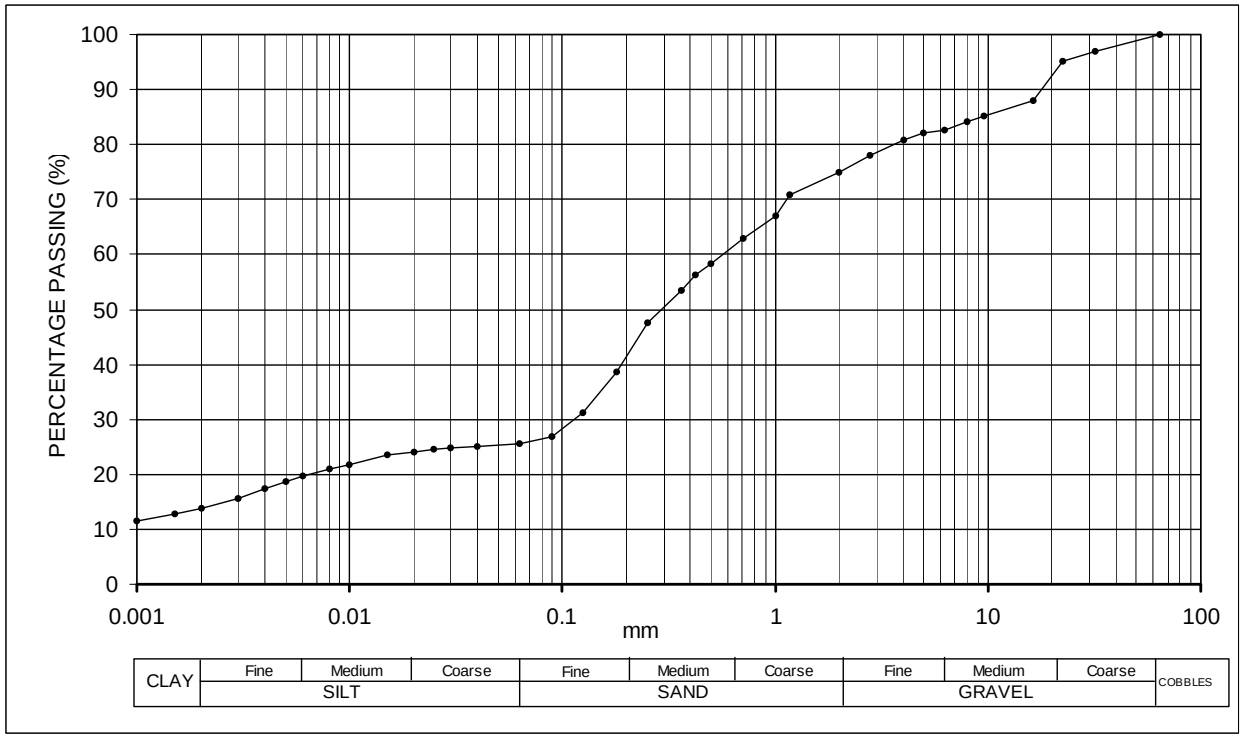
Project: UK soils and rocks: Till **Area** Nairn
Site: Riereach Burn 1
Sample: 1
Grid Reference 285987E 839975N
Description Compact light olive brown (2.5Y5/4) SILT interbedded with 10 -30mm thick beds of laminated (laminations 5 - 20 mm) medium to coarse SAND and occasional medium to coarse gravel of psammite, gneiss and sandstone. Occasional boulder up to 300 mm
Laboratory No. 129/1

Course **Fine**

Total Sample Weight 2106.40 **g**
Retained Sample Weight 1647.32 **g** **Passing 63µm Sieve** 459.08 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	6	0.00	0.00	0.0	100.0
32	5	65.90	65.90	3.1	96.9
22.4	-4.50	102.40	168.30	8.0	92.0
16.3	-4.00	149.83	318.13	15.1	84.9
9.53	-3.25	60.55	378.68	18.0	82.0
8	-3.00	21.12	399.80	19.0	81.0
6.3	-2.66	33.40	433.20	20.6	79.4
5	-2.32	12.43	445.63	21.2	78.8
4	-2.00	39.27	484.90	23.0	77.0
2.8	-1.50	57.21	542.11	25.7	74.3
2.000	-1.00	62.57	604.68	28.7	71.3
1.180	-0.25	87.66	692.34	32.9	67.1
1.000	0.00	78.41	770.75	36.6	63.4
0.710	0.50	90.27	861.02	40.9	59.1
0.500	1.00	96.91	957.93	45.5	54.5
0.425	1.25	44.23	1002.16	47.6	52.4
0.360	1.75	59.11	1061.27	50.4	49.6
0.250	2.00	123.64	1184.91	56.3	43.7
0.180	2.50	188.38	1373.29	65.2	34.8
0.125	3.00	154.41	1527.70	72.5	27.5
0.090	3.50	90.47	1618.17	76.8	23.2
0.063	4.00	29.15	1647.32	78.2	21.8

Sieve Size (mm)	% Passing	Actual %
0.060	100.0	21.8
0.050	99.6	21.7
0.040	98.6	21.5
0.030	96.8	21.1
0.025	95.9	20.9
0.020	94.4	20.6
0.015	92.0	20.0
0.010	85.4	18.6
0.0080	81.8	17.8
0.0060	77.2	16.8
0.0050	73.5	16.0
0.0040	68.2	14.9
0.0030	61.2	13.3
0.0020	54.3	11.8
0.0015	50.1	10.9
0.0010	44.7	9.7



RIEREACH BURN SITE 1, SAMPLE NO. 2 (129/2) [GR 284531 843153]

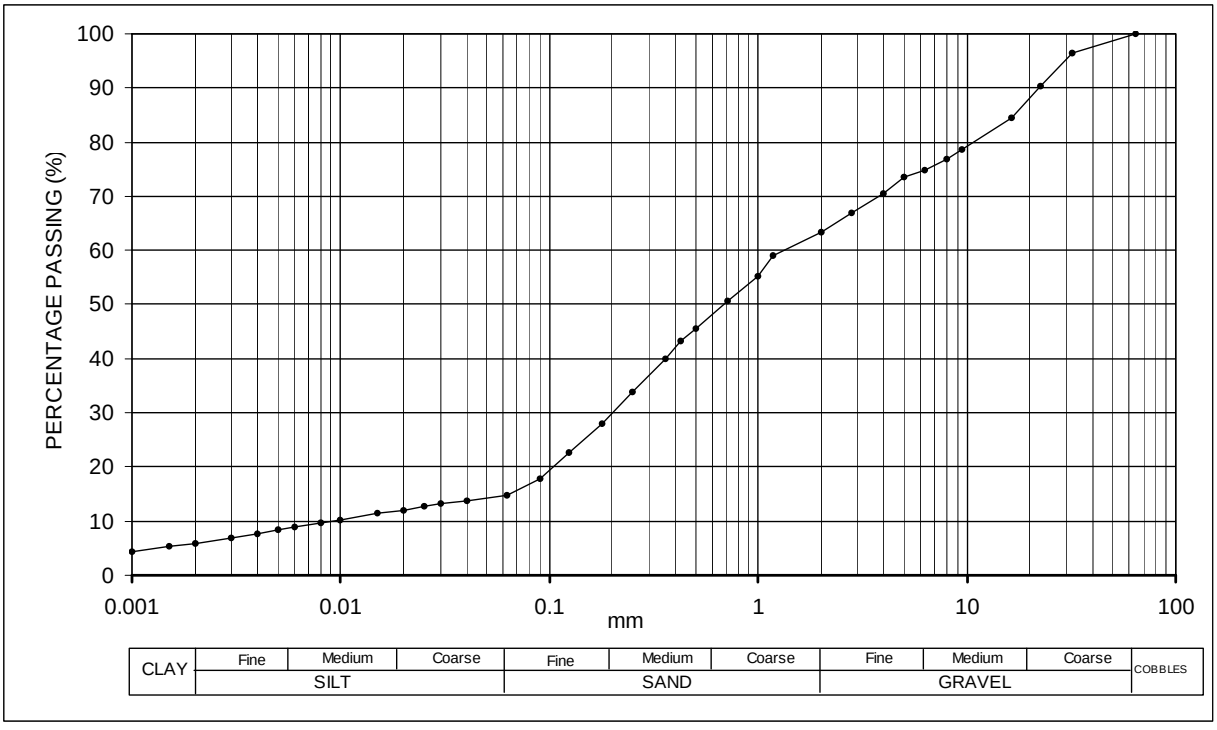
Project: UK soils and rocks: Till **Area** Nairn
Site: Riereach Burn 1
Sample: 2
Grid Reference 284531E 843153N
Description Very dense reddish grey (5YR5/2) slightly clayey gravelly fine to coarse SAND. Gravel is fine to coarse subangular to rounded of sandstone, granite and psammite. Occasional boulder up to 300 mm
Laboratory No. 129/2

Course
Total Sample Weight 2705.00 **g**
Retained Sample Weight 2308.67 **g**

Fine
Passing 63µm Sieve 396.33 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	-6.00	0.00	0.00	0.0	100.0
32	-5.00	98.50	98.50	3.6	96.4
22.4	-4.50	160.00	258.50	9.6	90.4
16.3	-4.00	159.17	417.67	15.4	84.6
9.53	-3.25	157.97	575.64	21.3	78.7
8	-3.00	47.50	623.14	23.0	77.0
6.3	-2.66	60.89	684.03	25.3	74.7
5	-2.32	31.55	715.58	26.5	73.5
4	-2.00	80.74	796.32	29.4	70.6
2.8	-1.50	99.16	895.48	33.1	66.9
2.000	-1.00	94.75	990.23	36.6	63.4
1.180	-0.25	118.01	1108.24	41.0	59.0
1.000	0.00	102.53	1210.77	44.8	55.2
0.710	0.50	124.16	1334.93	49.4	50.6
0.500	1.00	138.31	1473.24	54.5	45.5
0.425	1.25	63.54	1536.78	56.8	43.2
0.360	1.75	84.64	1621.42	59.9	40.1
0.250	2.00	169.28	1790.70	66.2	33.8
0.180	2.50	158.33	1949.03	72.1	27.9
0.125	3.00	144.71	2093.74	77.4	22.6
0.090	3.50	126.02	2219.76	82.1	17.9
0.063	4.00	88.91	2308.67	85.3	14.7

Size (mm)	% Passing	Actual %
0.060	100.0	14.7
0.050	98.1	14.4
0.040	94.4	13.8
0.030	89.7	13.1
0.025	86.3	12.6
0.020	81.6	11.9
0.015	77.4	11.3
0.010	69.0	10.1
0.0080	65.6	9.6
0.0060	60.8	8.9
0.0050	57.6	8.4
0.0040	51.6	7.6
0.0030	46.5	6.8
0.0020	40.5	5.9
0.0015	35.6	5.2
0.0010	29.6	4.3



RIEREACH BURN SITE 2, SAMPLE NO. 1 (129/3) [GR 284531 844127]

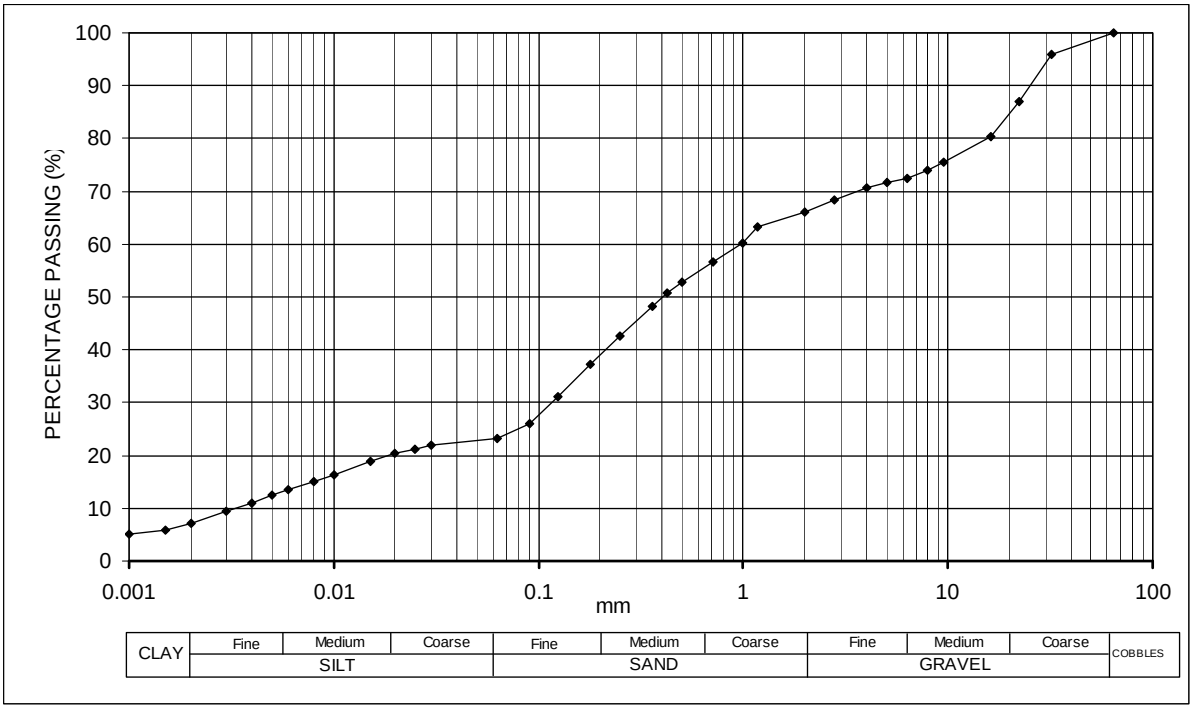
Project: UK soils and rocks: Till **Area** Nairn
Site: Riereach Burn 2
Sample: 1
Grid Reference 284531E 844127N
Description Dense to very dense cobbley, silty very gravelly SAND
Laboratory No. 129/3

Course **Fine**

Total Sample Weight 1937.10 **g**
Retained Sample Weight 1505.66 **g** **Passing 63µm Sieve** 431.44 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	-6.0	0.00	0.00	0.0	100.0
32	-5.0	80.10	80.10	4.1	95.9
22.4	-4.50	173.20	253.30	13.1	86.9
16.3	-4.00	125.27	378.57	19.5	80.5
9.53	-3.25	94.09	472.66	24.4	75.6
8	-3.00	31.92	504.58	26.0	74.0
6.3	-2.66	28.84	533.42	27.5	72.5
5	-2.32	16.42	549.84	28.4	71.6
4	-2.00	36.88	586.72	30.3	69.7
2.8	-1.50	44.33	631.05	32.6	67.4
2.000	-1.00	44.63	675.68	34.9	65.1
1.180	-0.25	50.37	726.05	37.5	62.5
1.000	0.00	61.03	787.08	40.6	59.4
0.710	0.50	70.2	857.28	44.3	55.7
0.500	1.00	72.48	929.76	48.0	52.0
0.425	1.25	39.11	968.87	50.0	50.0
0.360	1.75	52.24	1021.11	52.7	47.3
0.250	2.00	106.07	1127.18	58.2	41.8
0.180	2.50	106.27	1233.45	63.7	36.3
0.125	3.00	116.49	1349.94	69.7	30.3
0.090	3.50	99.80	1449.74	74.8	25.2
0.063	4.00	55.92	1505.66	77.7	22.3

Sieve Size (mm)	% Passing	Actual %
0.060	99.8	22.2
0.050	99.4	22.1
0.040	98.0	21.8
0.030	94.6	21.1
0.025	92.1	20.5
0.020	88.6	19.7
0.015	81.9	18.2
0.010	71.0	15.8
0.0080	65.3	14.6
0.0060	58.6	13.0
0.0050	53.9	12.0
0.0040	47.4	10.6
0.0030	40.6	9.0
0.0020	30.9	6.9
0.0015	24.9	5.5
0.0010	22.6	5.0



RIEREACH BURN SITE 2, SAMPLE NO. 2 (129/4) [GR 284524 844136]

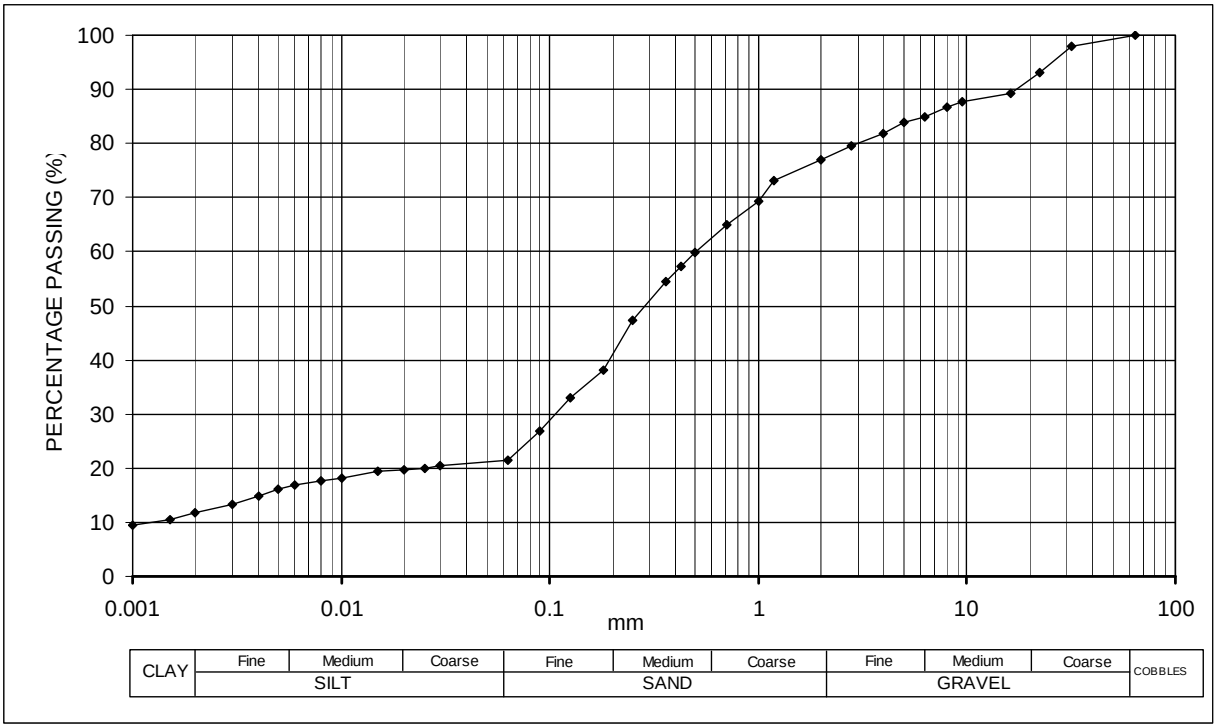
Project: UK soils and rocks: Till **Area** Nairn
Site: Riereach Burn 2
Sample: 2
Grid Reference 284524E 844136N
Description Very dense, silty, cobbley, very gravelly SAND
Laboratory No. 129/4

Course **Fine**

Total Sample Weight 1123.20 **g**
Retained Sample Weight 882.86 **g** **Passing 63µm Sieve** 240.34 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	-6.0	0.00	0.00	0.0	100.0
32	-5.0	24.00	24.00	2.1	97.9
22.4	-4.50	52.91	76.91	6.8	93.2
16.3	-4.00	42.44	119.35	10.6	89.4
9.53	-3.25	19.13	138.48	12.3	87.7
8	-3.00	11.76	150.24	13.4	86.6
6.3	-2.66	19.48	169.72	15.1	84.9
5	-2.32	10.59	180.31	16.1	83.9
4	-2.00	22.70	203.01	18.1	81.9
2.8	-1.50	27.55	230.56	20.5	79.5
2.000	-1.00	28.46	259.02	23.1	76.9
1.180	-0.25	42.63	301.65	26.9	73.1
1.000	0.00	43.36	345.01	30.7	69.3
0.710	0.50	49.65	394.66	35.1	64.9
0.500	1.00	56.25	450.91	40.1	59.9
0.425	1.25	27.44	478.35	42.6	57.4
0.360	1.75	33.20	511.55	45.5	54.5
0.250	2.00	81.39	592.94	52.8	47.2
0.180	2.50	103.38	696.32	62.0	38.0
0.125	3.00	56.56	752.88	67.0	33.0
0.090	3.50	68.29	821.17	73.1	26.9
0.063	4.00	61.69	882.86	78.6	21.4

Sieve Size (mm)	% Passing	Actual %
0.060	99.1	21.2
0.050	98.8	21.1
0.040	97.6	20.9
0.030	95.3	20.4
0.025	93.8	20.1
0.020	92.0	19.7
0.015	90.7	19.4
0.010	85.0	18.2
0.0080	82.3	17.6
0.0060	78.8	16.9
0.0050	75.3	16.1
0.0040	69.6	14.9
0.0030	62.6	13.4
0.0020	54.5	11.7
0.0015	49.5	10.6
0.0010	43.8	9.4



RIEREACH BURN SITE 3, SAMPLE NO. 1 (129/5) [GR 284479 844052]

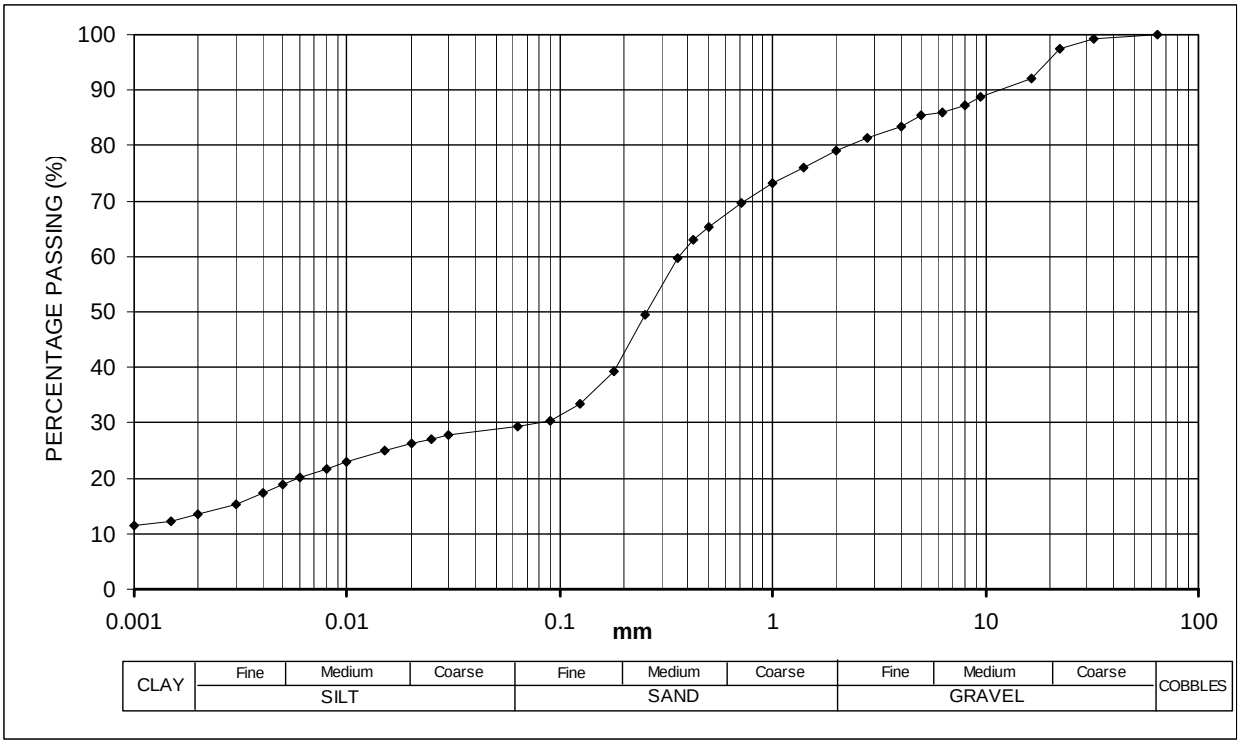
Project: UK soils and rocks: Till **Area** Nairn
Site: Riereach Burn 3
Sample: 1
Grid Reference 284479E 844052N
Description Dense to very dense brown (10YR5/3) slightly silty very gravelly fine to medium SAND with occasional cobbles and boulders. Gravel is fine to course subangular to rounded sandstone, granite, gneiss, quartzite and psammite.
Laboratory No. 129/5

Course **Fine**

Total Sample Weight 2305.10 **g**
Retained Sample Weight 1629.78 **g** **Passing 63µm Sieve** 675.32 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	-6.00	0.00	0.000	0.0	100.0
32	-5.00	17.10	17.100	0.7	99.3
22.4	-4.50	40.28	57.380	2.5	97.5
16.3	-4.00	125.30	182.68	7.9	92.1
9.53	-3.25	76.86	259.54	11.3	88.7
8	-3.00	32.24	291.78	12.7	87.3
6.3	-2.66	32.12	323.90	14.1	85.9
5	-2.32	14.14	338.04	14.7	85.3
4	-2.00	43.73	381.77	16.6	83.4
2.8	-1.50	50.14	431.91	18.7	81.3
2.000	-1.00	51.09	483.00	21.0	79.0
1.400	-0.25	69.29	552.29	24.0	76.0
1.000	0.00	64.55	616.84	26.8	73.2
0.710	0.50	81.03	697.87	30.3	69.7
0.500	1.00	102.69	800.56	34.7	65.3
0.425	1.25	50.78	851.34	36.9	63.1
0.360	1.75	78.32	929.66	40.3	59.7
0.250	2.00	234.05	1163.71	50.5	49.5
0.180	2.50	237.21	1400.92	60.8	39.2
0.125	3.00	136.55	1537.47	66.7	33.3
0.090	3.50	65.23	1602.70	69.5	30.5
0.063	4.00	27.08	1629.78	70.7	29.3

Sieve Size (mm)	% Passing	Actual %
0.060	100.0	29.3
0.050	99.5	29.2
0.040	98.2	28.8
0.030	94.8	27.8
0.025	92.0	27.0
0.020	89.4	26.2
0.015	85.6	25.1
0.010	78.8	23.1
0.0080	74.3	21.8
0.0060	68.9	20.2
0.0050	64.8	19.0
0.0040	59.0	17.3
0.0030	52.6	15.4
0.0020	46.2	13.5
0.0015	41.8	12.3
0.0010	39.0	11.4



DRYNACHAN BURN SITE 1, SAMPLE NO. 1 (129/6) [GR 285987 839975]

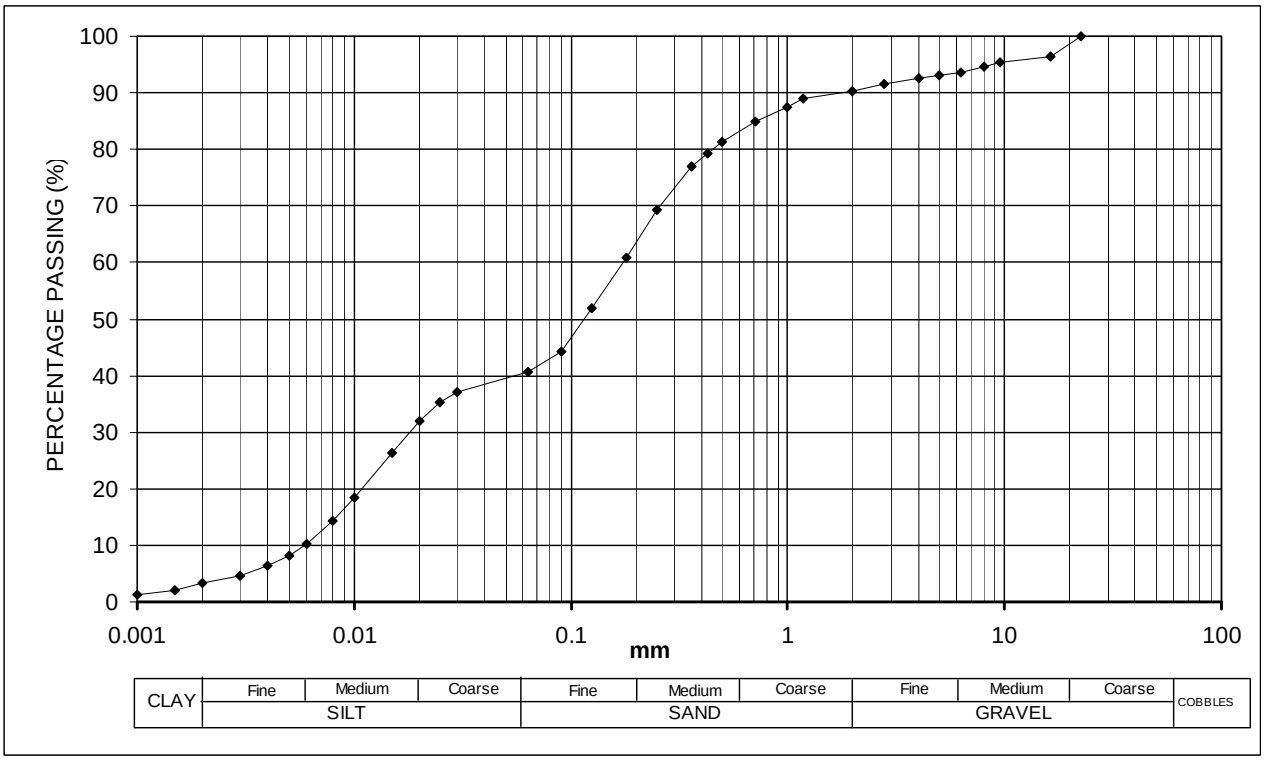
Project: UK rocks and soils: Till **Area** Nairn
Site: Drynachan section 1
Sample: 1
Grid Reference 285987E 839975N
Description Compact light olive brown (2.5Y5/4) SILT interbedded with 10 -30mm thick beds of laminated (laminations 5 - 20 mm) medium to coarse SAND and occasional medium to coarse gravel of psammite, gneiss and sandstone. Very occasional cobbles.
Laboratory No. 129/6

Course **Fine**

Total Sample Weight 1421.90 **g**
Retained Sample Weight 850.98 **g** **Pass 0.63 mm sieve** 570.92 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
22.4	-4.50	0.00	0.00	0.0	100.0
16.3	-4.00	51.07	51.07	3.6	96.4
9.53	-3.25	15.99	67.06	4.7	95.3
8	-3.00	8.81	75.87	5.3	94.7
6.3	-2.66	14.27	90.14	6.3	93.7
5	-2.32	7.98	98.12	6.9	93.1
4	-2.00	14.73	112.85	7.9	92.1
2.8	-1.50	16.45	129.30	9.1	90.9
2.000	-1.00	17.19	146.49	10.3	89.7
1.180	-0.25	19.18	165.67	11.7	88.3
1.000	0.00	20.76	186.43	13.1	86.9
0.710	0.50	34.30	220.73	15.5	84.5
0.500	1.00	52.83	273.56	19.2	80.8
0.425	1.25	28.78	302.34	21.3	78.7
0.360	1.75	34.17	336.51	23.7	76.3
0.250	2.00	107.10	443.61	31.2	68.8
0.180	2.50	121.29	564.90	39.7	60.3
0.125	3.00	126.81	691.71	48.6	51.4
0.090	3.50	109.73	801.44	56.4	43.6
0.063	4.00	49.54	850.98	59.8	40.2

Sieve Size (mm)	% Passing	Actual %
0.060	99.0	39.7
0.050	98.3	39.5
0.040	96.5	38.7
0.030	92.5	37.1
0.025	88.0	35.3
0.020	79.3	31.8
0.015	65.9	26.5
0.010	45.7	18.3
0.0080	35.5	14.2
0.0060	25.2	10.1
0.0050	20.5	8.2
0.0040	15.8	6.3
0.0030	11.7	4.7
0.0020	8.2	3.3
0.0015	5.2	2.1
0.0010	3.4	1.4



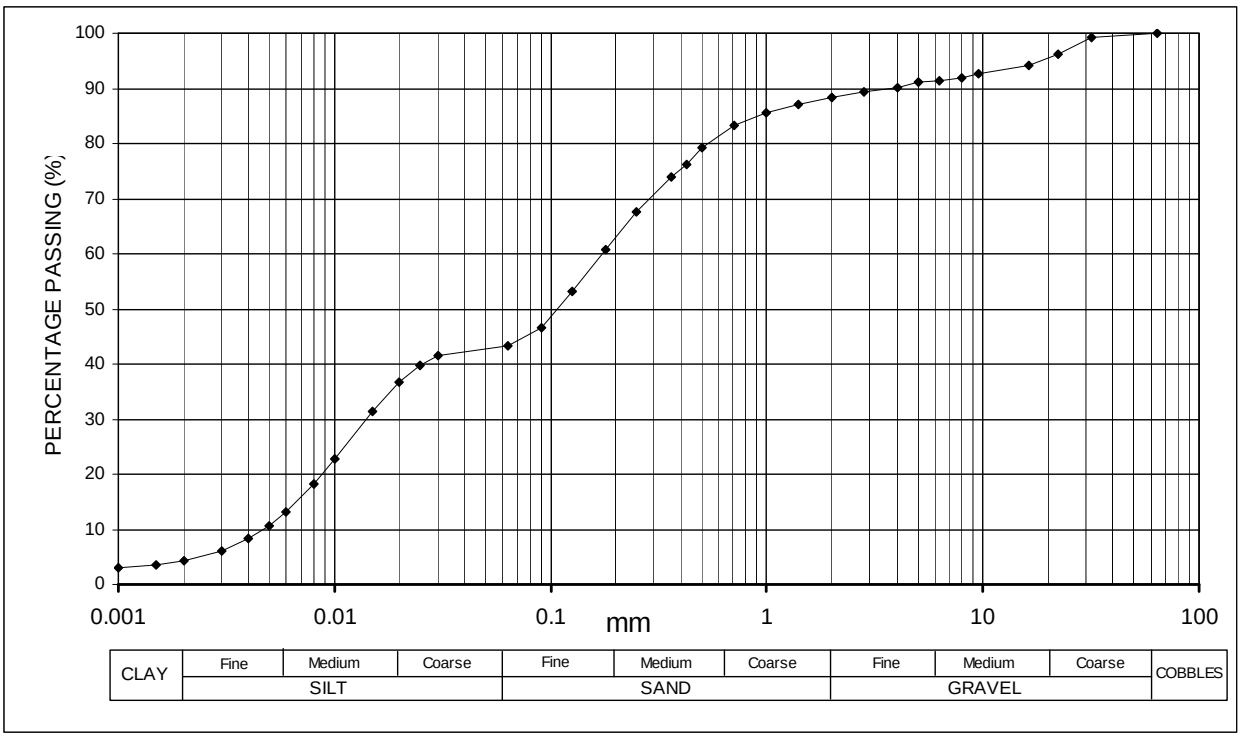
DRYNACHAN BURN SITE 1, SAMPLE NO. 2 (129/7) [GR 285987 839975]

Project: UK soils and rocks: Till **Area** Nairn
Site: Drynachan section 1
Sample: 2
Grid Reference 285987E 839975N
Description Compact light olive brown (2.5Y5/4) SILT interbedded with 10 -30mm thick beds of laminated (laminations 5 - 20 mm) gravelly medium to coarse SAND. Gravel is medium to coarse gravel of psammite, gneiss and sandstone.Very occasional cobbles
Laboratory No. 129/7

Course **Fine**
Total Sample Weight 1571.40 **g**
Retained Sample Weight 890.390 **g** **Passing 63µm Sieve** 681.01 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	-6.0	0.00	0.00	0.0	100.0
32	-5.0	10.00	10.00	0.6	99.4
22.4	-4.50	49.83	59.83	3.8	96.2
16.3	-4.00	32.57	92.40	5.9	94.1
9.53	-3.25	23.13	115.53	7.4	92.6
8	-3.00	10.88	126.41	8.0	92.0
6.3	-2.70	6.97	133.38	8.5	91.5
5	-2.70	7.68	141.06	9.0	91.0
4	-2.00	14.08	155.14	9.9	90.1
2.8	-1.50	13.35	168.49	10.7	89.3
2.000	-1.00	14.99	183.48	11.7	88.3
1.400	-0.25	18.07	201.55	12.8	87.2
1.000	0.00	25.02	226.57	14.4	85.6
0.710	0.50	37.37	263.94	16.8	83.2
0.500	1.00	62.09	326.03	20.7	79.3
0.425	1.25	47.26	373.29	23.8	76.2
0.360	1.75	35.52	408.81	26.0	74.0
0.250	2.00	99.93	508.74	32.4	67.6
0.180	2.50	109.04	617.78	39.3	60.7
0.125	3.00	119.70	737.48	46.9	53.1
0.090	3.50	101.17	838.65	53.4	46.6
0.063	4.00	51.74	890.39	56.7	43.3

Sieve Size (mm)	% Passing	Actual %
0.060	100.0	43.3
0.050	99.8	43.2
0.040	99.0	42.9
0.030	95.7	41.4
0.025	91.8	39.7
0.020	85.0	36.8
0.015	72.5	31.4
0.010	52.8	22.9
0.0080	42.2	18.3
0.0060	30.6	13.2
0.0050	24.8	10.8
0.0040	19.2	8.3
0.0030	13.9	6.0
0.0020	9.8	4.3
0.0015	7.9	3.4
0.0010	6.8	2.9



DRYNACHAN BURN SITE 2, SAMPLE NO. 1 (129/8) [GR 286035 839963]

Project: UK soils and rocks: Till **Area** Nairn
Site: Drynachan section 2
Sample: 1
Grid Reference 286035E 839963N
Description Compact light olive brown (2.5Y5/4) slightly gravelly, very sandy SILT. Gravel is fine to coarse.
Laboratory No. 129/8

Course
Total Sample Weight 1476.30 **g**
Retained Sample Weight 461.94 **g**

Fine
Passing 63µm Sieve 1014.36 g

Sieve Size (mm)	Sieve Size (ø)	Retained Weight (g)	Total (g) Retained	% Retained	% Passing
64	6	0.00	0.00	0	100.00
32	5	10.00	10.00	0.7	99.3
22.5	-4.50	21.71	31.71	2.1	97.9
16	-4.00	0.00	31.71	2.1	97.9
9.53	-3.25	1.35	33.06	2.2	97.8
8	-3.00	6.64	39.70	2.7	97.3
6.3	-2.66	2.00	41.70	2.8	97.2
5	-2.32	0.25	41.95	2.8	97.2
4	-2.00	4.10	46.05	3.1	96.9
2.8	-1.49	5.08	51.13	3.5	96.5
2.000	-1.00	5.61	56.74	3.8	96.2
1.400	-0.49	10.93	67.67	4.6	95.4
1.000	0.00	12.53	80.20	5.4	94.6
0.710	0.49	15.73	95.93	6.5	93.5
0.500	1.00	21.42	117.35	7.9	92.1
0.425	1.23	12.68	130.03	8.8	91.2
0.360	1.47	23.17	153.20	10.4	89.6
0.250	2.00	65.14	218.34	14.8	85.2
0.180	2.47	99.92	318.26	21.6	78.4
0.125	3.00	78.98	397.24	26.9	73.1
0.090	3.47	42.84	440.08	29.8	70.2
0.063	3.99	21.86	461.94	31.3	68.7

Sieve Size (mm)	% Passing	Actual %
0.060	100.0	68.7
0.050	100.0	68.7
0.040	99.7	68.5
0.030	97.1	66.8
0.025	93.4	64.2
0.020	86.4	59.4
0.015	73.3	50.4
0.010	51.9	35.6
0.0080	40.8	28.0
0.0060	28.8	19.8
0.0050	22.8	15.7
0.0040	16.5	11.4
0.0030	10.5	7.2
0.0020	5.9	4.1
0.0015	4.1	2.8
0.0010	3.4	2.4