Forest Research

Potential for woodland restoration above the A83 in Glen Croe to reduce the incidence of water erosion and debris flows

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Contents

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Background

This assessment was instigated by Forestry Commission Scotland, with the aim of appraising the suitability of the hill watershed directly above the A83 at the 'Rest and Be Thankful' in Glen Croe for tree planting and the potential for the trees and shrubs to reduce the incidence of debris flows onto the A83. Transport Scotland have already commenced a programme of installing engineered catch fencing and improved drainage to counteract the immediate potential effects of debris flows toward the A83. Planting is one option for consideration that could form part of a future package of measures being discussed for the wider area around the problem section of the A83.

The current owner of the land currently runs ~200 head of sheep on the hill ground above the road, with a further 40 – 50 head of cattle (beef suckler) being put onto the hill during the summer months, to reduce the spread of course grasses and bracken. There is an unknown transient deer population, which is largely hefted within the surrounding forest blocks; they too have a significant influence upon the hill. The future management of the site will depend on the intentions of the owner, and this report is intended to aid discussions about the possibilities for improving site stability.

Site Conditions

Climate

The Forestry Commission Decision Support System, 'Ecological Site Classification' (ESC) (Pyatt et al, 2001) provides objective baseline site data, at a scale of 100m (See Appendix 1). The following climatic ranges affect the potential planting area:

Accumulated Temperature 5°C, day degrees

Accumulated temperature data are the sum of daily hours, when the average temperature exceeds 5°C throughout the year. The hours are summed, and then divided by 24, to give day degrees value for a site. These data provide a good indication of the potential length of the plant growing season at any particular point across a site. The range across this watershed from the lowest point in the southern corner immediately adjacent to the A83 (NGR NN 242 063) to the top of Beinn Luibheah (NGR NN 243 079) is **1113°** to **320°**, with mid slope at 450m (NGR NN 239 073) value of **741°**.

The significance of these data is that the mid-slope value of **741°** represents the lower end of the accumulated temperature range where native broadleaves may readily be established.

Moisture Deficit (mm)

Moisture deficit reflects the balance between potential evaporation and rainfall and therefore emphasises the dryness of the growing season (rather than the wetness of the winter or whole year). These data indicate the potential likelihood of drought rooting conditions occurring on a site during the growing period.

The same points used for AT5 assessment, give the following value range **69 mm to -82 mm** with a mid-slope value of **-2 mm**. This shows that the trees are unlikely to encounter drought rooting conditions, especially above the mid slope position, where precipitation exceeds evaporation, this is why there are negative values in the data.

Exposure - Detailed Aspect Method of Scoring (DAMS)

These data indicate the potential exposure of a site, with the associated constraints on tree growth that this brings; desiccation, physical damage to the plant and uprooting (if and when the wind load on the tree crown is greater than the root anchorage can resist). On sites such as this, windthrow reduces the ability of the trees/shrubs to bind the surface and increases the site susceptibility to debris flow. Using the same national grid reference points (NGR), the following DAMS value range was obtained: **13.3 to 28.4** with a mid slope value of **19.2**.

These data show that once above an elevation of ~450m, exposure alone will hinder the establishment of all tree and shrub species on this site.

Continentality

The Conrad index of continentality was derived for Britain from the mean annual temperature range and the geographical latitude and divided into four classes by Bendelow and Hartnup (1980). These data indicate the 'Oceanicity' or 'Continentality' of the site and usually show little or no variation across any specific site. Glen Croe is no exception and has a figure across the site of **4.5**.

This indicates an 'Oceanic' climate pattern for the site. **Warm, moist summers** and **Cool, wet winters**.

Geology

Using the British Geological Survey (BGS) 1:625,000 Bedrock (solid) data, the site predominantly lies upon Quartz-mica-schist, grit, slate and phyllite (Upper Dalradian) (19). Occupying an area in the southern part of the site there is an intrusion of Diorite and allied intermediate types (Early Devonian) (33). (N.B. the numeric characters in parenthesis are those used by the BGS in their map legend)

Overlying these bedrocks are deposits of varying depth of glacial till and colluvial material derived from the bedrock.

Soils

The soils derived from the Quartz-mica-schist, grit, slate and phyllite have 'Moderate' potential nitrogen (N) availability from the bedrock. The soils derived from the Diorite intrusion have 'High' potential nitrogen (N) availability from the bedrock.

Soil textures are predominantly sandy silt to silt loam, this being derived from the parent bedrock constituent particles. These fine textured soils are known to be susceptible to erosion and debris flows under conditions of steep slopes and high rainfall. This is further exacerbated by the inclusion of mica particles within the soil, with their smooth, slippery surface offering little adhesion or structural strength.

Soil profiles are described here using the Soil Survey of England and Wales notation (Technical Monograph No. 5, Hodgson, 1974) and the Forestry Commission Soil Classification (Kennedy, 2002).

Below ~400m elevation the soils are predominantly mineral soils, with varying degrees of podzolisation and incipient gleying being visible through the profiles. Above ~400m there is a notable rapid increase in depth of raw organic matter (O) on the surface of the mineral layers and this combines with an increasing proportion of shallow (<40cm to bedrock), skeletal soils and rankers (<30cm depth to bedrock) soils. Many of the soil profiles show evidence of having been derived from discontinuous soil movements down the slope and separate from the parent colluvium or parent bedrock.

There is also a topographic pattern in the location of the soil types. The convex slopes below ~400m having principally freely draining upland brown earth (1u), intergrade ironpan (4b) and brown surface-water gley (7b) soils. The concave slopes being surface-water gley (7), with occasional small linear features of peaty surface-water gley (6) and flushed Juncus peat (8). When the elevation exceeds ~400m, the convex slopes increasingly are podzolic ironpan soils (4z), skeletal or ranker soils (13) amongst scree (13s) and bedrock (13r). Whilst the concavities continue to contain shallow gleys (7la), some of which are peaty (6la). (N.B. The alpha-numeric codes in parenthesis refer to these soil types in the FC soil classification)

These soil types indicate that the range of the Soil Moisture Regime (SMR) across the site is from 'Moist' to 'Very Wet'.

Potential drainage pattern

A potential drainage pattern was derived from the analysis of Ordnance Survey DEM NN20 10km x 10km data tile, using MapMaker v3.5 (See Appendix 2). This map enables the potential drainage pattern of the site to be viewed.

Vegetation

The soil parent materials in Glen Croe have inherent moderate potential nitrogen availability and this inherent potential site fertility and a plentiful supply of moisture results in vegetation growth on these soils being luxuriant, where climatic conditions permit.

The present stocking density of both domestic and wild grazers and browsers is sufficient to maintain a short, heavily grazed sward across the whole of the site. This grazing pressure is reflected in the main plant species seen and their ability to resist this pressure.

The presence of flowering bluebell (*Hyacithoides non-scripta*), was a good indicator of the potential fertility of much of the site, below the ~400m elevation contour. None were observed above this elevation, but may exist in isolated groups and this indicates the increasing severity of the climate.

There were also a few tree seedlings seen, Downy Birch (*Betula pubescens*) and some Rowan (*Sorbus aucuparia*). These had been heavily grazed and only the occasional Rowan was seen growing from a rock fissure, or other inaccessible site, where it had avoided being browsed or burnt. There were some small, Eared willow (*Salix aurita*) seedlings adjacent to the roadside, but these have been readily grazed out elsewhere across the site.

The following is a short list of “typical of the site” plant species found in addition to those already mentioned:

Wavy hair-grass (*Deschampsia flexuosa*)

Tufted hair-grass (*Deschampsia cespitosa*)

Mat-grass (*Nardus stricta*)

Common bent (*Agrostis capillaris*)

Yorkshire Fog (*Holcus lanatus*)

Purple moor-grass (*Molinia caerulea*) (sparse)

Bracken (*Pteridium aquilinum*)

Creeping buttercup (*Ranunculus repens*)

Soft rush (*Juncus effusus*)

Heath woodrush (*Luzula multiflora*) (sparse)

Blaeberry (*Vaccinium myrtillus*) (sparse)

Heather (*Calluna vulgaris*)

Wood anemone (*Anemone nemorosa*) (sparse)

The majority of these species, by their frequency, indicate that the potential Soil Nutrient Regime (SNR) is ‘Poor’ to ‘Medium’ across the site.

Potential effects of cloven hooved and other grazing animals on site stability

Grazing by domesticated and wild animals can alter the ground vegetation. In the uplands, heavy grazing by sheep and deer causes a decline in heather cover which is then replaced by tussock forming grasses with poorer soil binding abilities. However, one difficulty in establishing links between soil erosion and grazing is that historic stocking densities, which are generally unknown, may have had more influence on the risk of erosion than current stocking densities. Also, both sheep and deer will preferentially graze specific areas, resulting in localised areas experiencing greater grazing pressures and an increased risk of erosion. Innes (1983) considered that at Beinn Achaladair, overgrazing by sheep may have been a contributory factor in the occurrence of landslides.

On our site visit, poaching of the site by both cattle and sheep in some areas was seen to exceed the following recommendation provided by DEFRA (2005):

"From healthy pasture to mud can take just 2-3 days. When the soil dries out again, it is often badly compacted. This can lead to poor spring growth and loss of grass yield. Weeds and inferior grasses take over …. As a guide, if hoof marks from cattle appear, which are deeper than 50 mm (2") then move stock immediately from at risk sites. (http://archive.defra.gov.uk/environment/quality/land/soil/documents/soilerosion-combinedleaflets.pdf)"

There is further recognition of the potential for sheep and deer stocking numbers to exacerbate the potential erosion of a steep slope published by Scottish Natural Heritage (http://www.snh.org.uk/publications/on-line/advisorynotes/43/43.htm):

"1.6 It is difficult to separate the effects of grazing from other factors, but it has been shown in several areas that increased sheep numbers may lead to the creation of bare ground subject to erosion. Peat soils, particularly on cut-over sites, are more vulnerable than mineral soils.

1.7 Even where overall stocking rates are causing no effect, localised erosion can be initiated if stock is concentrated. This can occur around supplementary feeding sites, gates, and well-used pathways between favoured grazing areas.

1.8 By preventing or hindering revegetation sheep grazing may maintain or exacerbate erosion initiated by other causes. For example, this can be a danger on recently burnt areas particularly if the area burnt is small relative to the stock numbers, which may be attracted by the fresh regrowth. Scars on slopes, created by sheep rubbing and used by them for shelter and resting, may extend annually and may result in considerable amounts of soil erosion. On mineral soils in the Lake District, grazing pressures of 2.5 sheep per ha (all year round) or 5 sheep per ha (summer grazing only) are the critical densities for initiating scars. Peat is several times more vulnerable, and the critical threshold may be about 0.5 sheep ha (Summer grazing only).

1 9 Both scars and other forms of grazing induced erosion, if not severe, may become largely inactive and ultimately revegetate if stocking rates are reduced on the areas affected.

1.10 Cases of severe erosion are clearly associated with gross overstocking (e.g. 2.5 sheep per ha all year on blanket bog in Argyll). However, data which relates stocking levels to all the relevant factors (including soil, topography, altitude, precipitation, burning regime, drainage) is lacking. At present, site-specific stocking limits can only be set by experience and observation.

Red deer

1.11 The evidence for red deer causing increased peat hagging and other types of erosion is anecdotal and no objective data exist. However, being heavier than sheep, they may have the potential to cause similar effects at somewhat lower stocking densities, especially on steep slopes." (http://www.snh.org.uk/publications/on-line/advisorynotes/43/43.htm).

The James Hutton Institute (JHI) in its former guise as the Macaulay Land Use Research Institute (MLURI) has also published advice that includes the following observations:

"Compaction and poaching

Soil strength decreases significantly with wetness and, thus, access for machinery and animals should be restricted when soil moisture content is at or close to field capacity.

Natural regeneration of compacted top soils can take up to 3 years.

In the longer term, increasing soil organic matter contents in mineral soils can encourage the development of good soil structure. Poaching damage by livestock is again amenable to good land management practices. Limiting access of stock to wet soils and fencing of sensitive areas, such as river banks, can all help at the farm level." (http://www.macaulay.ac.uk/aweg/factsheetsoilphysicaldam.pdf)

Potential effects of previous muirburn on site stability

Muir burning may have been used to manage vegetation structure and improve the productivity of the hill ground in Glen Croe. Damage to the soil can be caused by uncontrolled or inappropriate burning when it removes too much vegetation cover. A severe burn, creating high soil temperatures, can make the surface organic layer water repellent or remove it from the site. These actions result in greater water run-off and a greater potential for soil erosion and landslides. Innes (1983), suggested increased landslide activity in the last few hundred years was partly related to burning, although this view is disputed by Brazier and Ballantyne (1989).

There is further recognition of the potential for muirburn to exacerbate the potential erosion of a steep slope published by Scottish Natural Heritage (SNH):

"1.12 The burning of heather or grass is a potential cause of erosion but, while catastrophic fires under very dry conditions can result in severe erosion which may persist for decades, the effect of well planned and well controlled muirburn is small and has not been shown to produce significant long-term impacts.

1.13 Following burning, loss of plant cover reduces both interception of precipitation and evapotranspiration, increasing the possibility of soil saturation. Movement of soil particles by raindrop impact is enhanced. However, the absence of plant cover means that wind speeds at the ground surface are higher and this may aid evaporative loss. Water infiltration is reduced in some soils by clogging of the soil pores with fine ash, the development of a crust of charred organic matter and ash, or the distillation and deposition of organic compounds within the soil during the fire. This can lead to greater surface flows and concentration of drainage water, increasing the potential for erosion.

114 The impact of burning is dramatically increased if it damages or destroys the root mat which binds and protects the soil. This is particularly so if the fire is severe enough to burn into the humus or peat horizons of the soil. The resulting bare mineral soil or peat surfaces are readily eroded by wind and water. Also, the loss of the seed bank, continuing instability of the soil, and excessively variable moisture conditions unfavourable for seedling growth, mean that revegetation may be long delayed.

1.15 Periodic cool burns, which merely remove above ground vegetation and loose plant litter and are followed by rapid revegetation, are preferable to a situation in which there is a large accumulation of biomass which is potentially combustible in dry periods. In the latter situation any fire will be dangerously hot and may easily ignite the underlying peat, especially during a period of drought when the peat itself may be partially desiccated." (http://www.snh.org.uk/publications/on-line/advisorynotes/43/43.htm)

Potential contribution of trees to the site

There is considerable evidence from the scientific literature that trees and shrubs can reduce soil loss and rock fall from vulnerable slopes. There are also cases where vegetation has exacerbated problems, for example when uprooted in storms, and where woody debris has blocked culverts during storm events. However, at the landscape scale, the evidence indicates that the benefits of woody vegetation on steep slopes greatly outweigh the disadvantages. For example, where erosion rates have been examined for the effect of historical land-use change across a landscape, erosion rates under grazing land were found to be 5 to 6 times higher than they had been under scrub and 8 to 17 times higher than they were under native forest (Page and Trustrum 1997). The potential of trees and shrubs to exacerbate problems can usually be kept to a minimum by appropriate management, for example by keeping trees relatively small to reduce windthrow risk.

Vegetation on vulnerable slopes provides physical protection of the soil by canopy interception of rainfall (evaporation and attenuation), root water uptake (usage and storage of water, and transpiration) and improved soil cohesion through root reinforcement. The improvements these mechanisms provide to slope stability vary depending on the type and density of the vegetation. The protection provided will also vary through the year, with deciduous species providing greater canopy interception when in leaf than when leafless in winter months, and with all species taking up the most soil water during spring and summer months. Herbaceous species and grasses do provide protection to the soil, but this is increased greatly by the incorporation of shrubby species and trees with woody roots. The roots of woody species provide a much stronger, and commonly deeper, matrix in the soil, that allow the soil to be held together and anchored better to deeper layers and underlying rock than would be the case with herbaceous vegetation alone. Where woody species with different root forms are mixed together, there may be further benefits from providing a root matrix that is better anchored throughout the soil profile (Norris et al. 2008), and is less likely to contribute to the translational sliding that is observed more commonly where vegetation is shallow rooted.

The problems encountered on the Glen Croe site derive from extensive areas of translational sliding ('rafting'), which then develop into debris flows, during high rainfall events. At present there are no extensive binding root systems extending to greater than ~30cm depth across the hillside and this is exacerbating the inherent soil properties to erode and flow downhill.

Silvicultural options

Continuous cover forestry with conifers, although appropriate in many parts of the UK, is limited to lower wind risk areas, and is therefore not suitable for higher elevation, wind exposed sites (see Forestry Commission, 2008), such as above the A83 at Glen Croe where the 'DAMS' windiness score is above 13.

Conifer plantations managed using clearfell-replant systems are used in some parts of the world to stabilise vulnerable slopes. For example, in New Zealand, pine plantations have been used extensively to re-stabilise "steep-lands" that have exhibited severe erosion since removal of indigenous forest for livestock grazing pasture. This has been partially successful, but periodic erosion and debris flows are reported from these sites, when high rainfall events coincide with a 'vulnerability window' of 5 to 7 years between harvesting and re-establishment of a pine tree cover. Woody debris from tree harvesting, cause additional problems by increasing the volume of material flowing down-slope in these events.

Additionally, clearfell managed conifer plantations are vulnerable to wind-throw ("wind-blow") uprooting, that can exacerbate erosion. They also require a forest road network, to allow access for management, maintenance and harvesting, when wheeled and tracked machinery predominates. Therefore, commercial planting of tree species with a potential to gain large timber volumes and height increment would not be the best policy for these site conditions.

If soil protection is seen as the primary ecosystem service to be provided by tree cover, rather than wood production, other forms of woodland become more appropriate.

If planting is to from part of an overall strategy to decreasing instability at this site, then restoring the site to a cover of native broadleaf tree species that would have existed on the site before intensive sheep grazing and elevated deer numbers, should be the first consideration. Native broadleaf tree and shrub species could be expected to establish with appropriate preparation and management and provide a range of ecosystem services. An initial high level of management would be required to establish this type of vegetation cover. However, once established, a relatively low intensity of continuous management would be sufficient to maintain the woodland. The ecosystem services provided could include improved soil and rock fall protection, improved biodiversity, improved water quality, and carbon sequestration. However, the site has considerable browsing pressure from a combination of deer, sheep and cattle that must be addressed in any management scheme. Unless grazing pressure can be considerably reduced (less than 4 deer per square kilometre) (Armstrong, pers. comm. 2012), fencing will be required to allow woodland establishment. Extensive fencing of new woodland would however reduce the area of land available for sheep and cattle grazing, impacting the farm business on this site. Grazing animals following new routes around fences would increase the potential for erosion, also focusing deer into specific crossing points over the A83.

National Vegetation Classification (NVC) woodland communities and individual plant species, with potential for growing on the Glen Croe site.

The woodland communities and associated plants to be discussed, have been considered initially for their suitability to the site and then for there inherent ability to robustly form a cohesive, protective vegetation community upon the debris flow prone slopes of Glen Croe.

Species should be a mixture of native broadleaved species appropriate for this site with an emphasis on smaller tree species and shrubs that would be less vulnerable to wind uprooting.

Two NVC woodland communities appear to fit the site conditions well, from climatic, soil moisture and soil nutrient regime perspectives (Kirby and Whitbread, 1991).

In the upper part of the slope above ~400m, **W17 Oak-birch, with blaeberry dominated ground vegetation**. At this altitude and with an AT5 value of less than 1,000 day degrees, Oak is unlikely to form part of the community, but all the remaining component species should be present. The sub community 17d appears the most likely.

Over the majority of the slope below ~400m to the original drove/main road used prior to the 1930's, **W11 Oak-birch, with wood sorrel and bluebell dominated ground vegetation**. Again at the higher elevation, oak may only form a minor component of the habitat due to temperature constraints, but bluebell is common even at ~400m elevation. The continuum of sub-communities from the bottom to the top of the area being 11a – 11b.

Tree and shrub species considered suitable for the climatic and edaphic conditions on this site:

Ash (*Fraxinus excelsior*) Limited numbers within protective plantings on lower flushed slopes. Site fertility improver, may require active management to control tree height. Coppices. However, the recent introduction of Ash dieback (*Chalara fraxinea (C. fraxinea)*) into the UK may preclude the use of this tree species in the immediate future.

Aspen (*Populus trembaloides*) Extensive suckering root system aids site cohesion and site improving leaf fall. Palatable to browsers, it will require protection. Coppices.

Bird Cherry (*Prunus padus*) Resistant to heavy browsing, extensive suckering root system aids site cohesion. Important food plant for insects and birds. Coppices.

Blackthorn (*Prunus spinosa*) Resistant to heavy browsing, extensive suckering root system aids site cohesion. Coppices.

Common alder (*Alnus glutinosa*) Resistant to browsing, extensive suckering root system aids site cohesion. Nitrogen fixing with root nodule symbiotic bacteria. Grows in aerobic water logged soils. Coppices.

Downy birch (*Betula pubescens*) Potentially difficult to establish if incorrect provenance used. Important pioneer species, rapid growth, extensive root system, site improver. Coppices.

Eared willow (*Salix aurita*) Important pioneer species, rapid growth, extensive root system, site improver. Coppices. Readily establishes from sets and or poles. This species would be planted as poles, hammered perpendicularly into stream and gully sides, which will form roots at a range of depths, thereby potentially anchoring large volumes of soil. Early pollen source for insects.

Hawthorn (*Crataegus monogyna*) Resistant to heavy browsing, extensive deep rooting system aids site cohesion. Coppices. Important bird and insect food supply.

Hazel (*Corylus avellana*) Shade tolerant, extensive strong root system. Site improver. Coppices.

Holly (*Ilex aquifolium*) Resistant to heavy browsing, extensive deep rooting system aids site cohesion. Shade tolerant. Coppices. Important bird and insect food supply.

Rowan (*Sorbus aucuparia*) Resistant to heavy browsing, extensive, potentially deep rooting system aids site cohesion. Readily establishes as a pioneer species on a large range of soil/ site types. Coppices. Important bird and insect food supply.

Sessile Oak (*Quercus petraea*) Limited numbers within protective plantings on lower flushed slopes. Extensive deep rooting system aids site cohesion. Coppices. Good for biodiversity, but may require active management to control tree height.

Whilst there may be other exotic shrub and tree species that would grow on this site, their fecundity or susceptibility to fungal or insect attack prevents there inclusion in this list of potential planting species.

Less palatable shrub species for browsers including hawthorn, blackthorn and bird cherry would form part of the planting mix with the aim of keeping browsing pressure down on palatable species, after fencing is removed.

On the banks of both disturbed and undisturbed gullies, willow could be planted to provide a potentially rapid improvement to soil cohesion. These would be planted both within and out-with the fenced areas as their relative inaccessibility should keep browsing pressure down.

Conclusions and Proposal for woodland restoration

If planting is to from part of an overall strategy to decreasing instability above the A83 at the 'Rest and Be Thankful', then it will be necessary to balance the need for woodland establishment on this site with the need for maintained grazing. The analysis here indicates that it is realistic to expect successful establishment of trees on this site, and suitable species and climatic limits have been defined. Patches of woodland should be established adjacent to existing eroding or vulnerable gullies and watercourses. Some planting within the gullies and watercourses, avoiding areas of debris flow/ active mass movement, would also be appropriate. These woodland patches would include riparian zones on the lower parts of the slope, avoiding the civil engineering protection, but importantly should allow grazing animal movement laterally and vertically across the site. Patches of woodland would be established along each of the stream gullies on the site, by planting a mixture of species appropriate for the site. Grazing pressure could be reduced by deer culling and minimal stock fencing until woodland is established. It appears that grazing is preventing natural regeneration of tree and shrub species and has denuded the area of potential seed sources.

Planting shrubs and small to medium sized broadleaved trees adjacent to the potentially mobile areas of slab erosion and debris flow gullies could increase the potential stability of these areas. Because many of the shrub and tree species that we propose for planting are resistant to browsing, readily coppice or sucker from the roots, they retain the ability to bind the soil across the hillside to a depth of at least 100cm where soil depths and aeration allow. If these species are moved or buried by soil movement, but remain on the site, they are likely to sucker and continue to bind the soil, rather than dying, decomposing and leaving the soil unbound. Areas of dense planting of these species above the engineered slope restraints could prevent the overwhelming of these restraints, whilst not compromising potential road clearance operations.

Restoration may take up to 30 years or more across the site where climatic conditions are most severe. The extent of these remedial plantings and their potential expansion across the vulnerable slope will depend upon negotiation, and active management in perpetuity.

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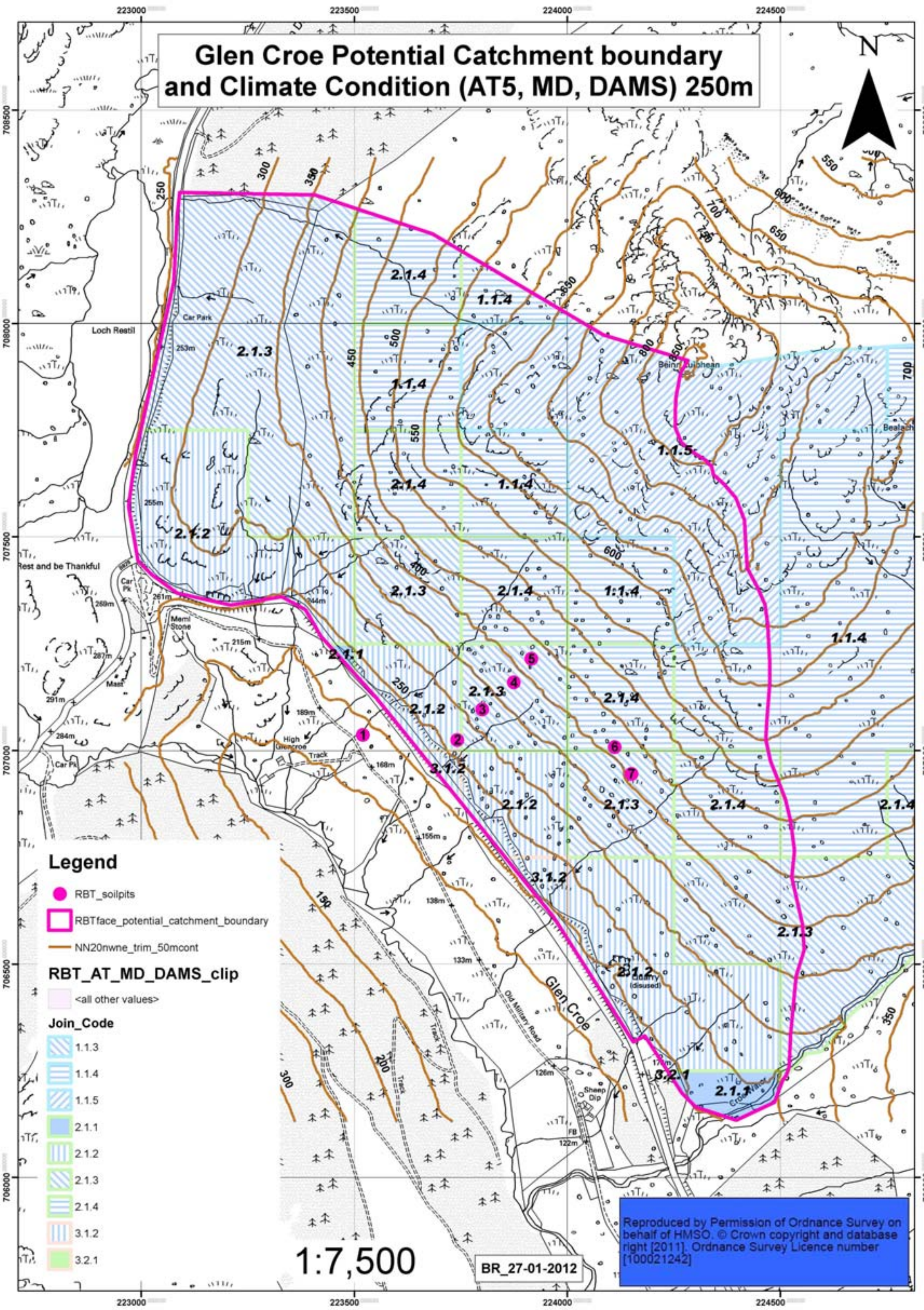
Appendix 1.


Glen Croe Potential Catchment boundary
and Climate Condition (AT5, MD, DAMS) 250m
N
Legend
RBT_soilpits
RBTface_potential_catchment_boundary
NN20nwne_trim_50mcont
RBT_AT_MD_DAMS_clip
<all other values>
Join_Code
1.1.3
1.1.4
1.1.5
2.1.1
2.1.2
2.1.3
2.1.4
3.1.2
3.2.1
1:7,500
BR_27-01-2012
Reproduced by Permission of Ordnance Survey on behalf of HMSO. © Crown copyright and database right [2011]. Ordnance Survey Licence number [100021242]
Loch Restil
Rest and be Thankful
Glen Croe
Old Military Road
Beinn Luibhean
High Glencroe
223000
223500
224000
224500
708500
708000
707500
707000
706500
706000

Appendix 1 Key

An explanation of the climatic 'join codes' used in the Appendix 1 map are given below.

Join code	**Explanation**		
1:1:3	AT5 <775 degree days	MD <90mm	DAMS =>16 <18
1:1:4	AT5 <775 degree days	MD <90mm	DAMS =>18 <22
1:1:5	AT5 <775 degree days	MD <90mm	DAMS =>22
2:1:1	AT5 775 – 1200 degree days	MD <90mm	DAMS <13
2:1:2	AT5 775 - 1200 degree days	MD <90mm	DAMS =>13 <16
2:1:3	AT5 775 - 1200 degree days	MD <90mm	DAMS =>16 <18
2:1:4	AT5 >1200 degree days	MD 90 –160mm	DAMS <13

Narrative for Appendix 1 map

The pink bordered shape on the map defines the catchment, from which debris flows have the potential to directly affect the A83 'Rest and Be Thankful' trunk road.

The brown lines across the map represent elevation contours at 50m intervals and their height above the OS Newlyn datum high water mark.

The colouring of the 250m x 250m grid squares, represents the three main climatic data used when assessing a sites suitability for growing trees and or Native Woodland Communities:-

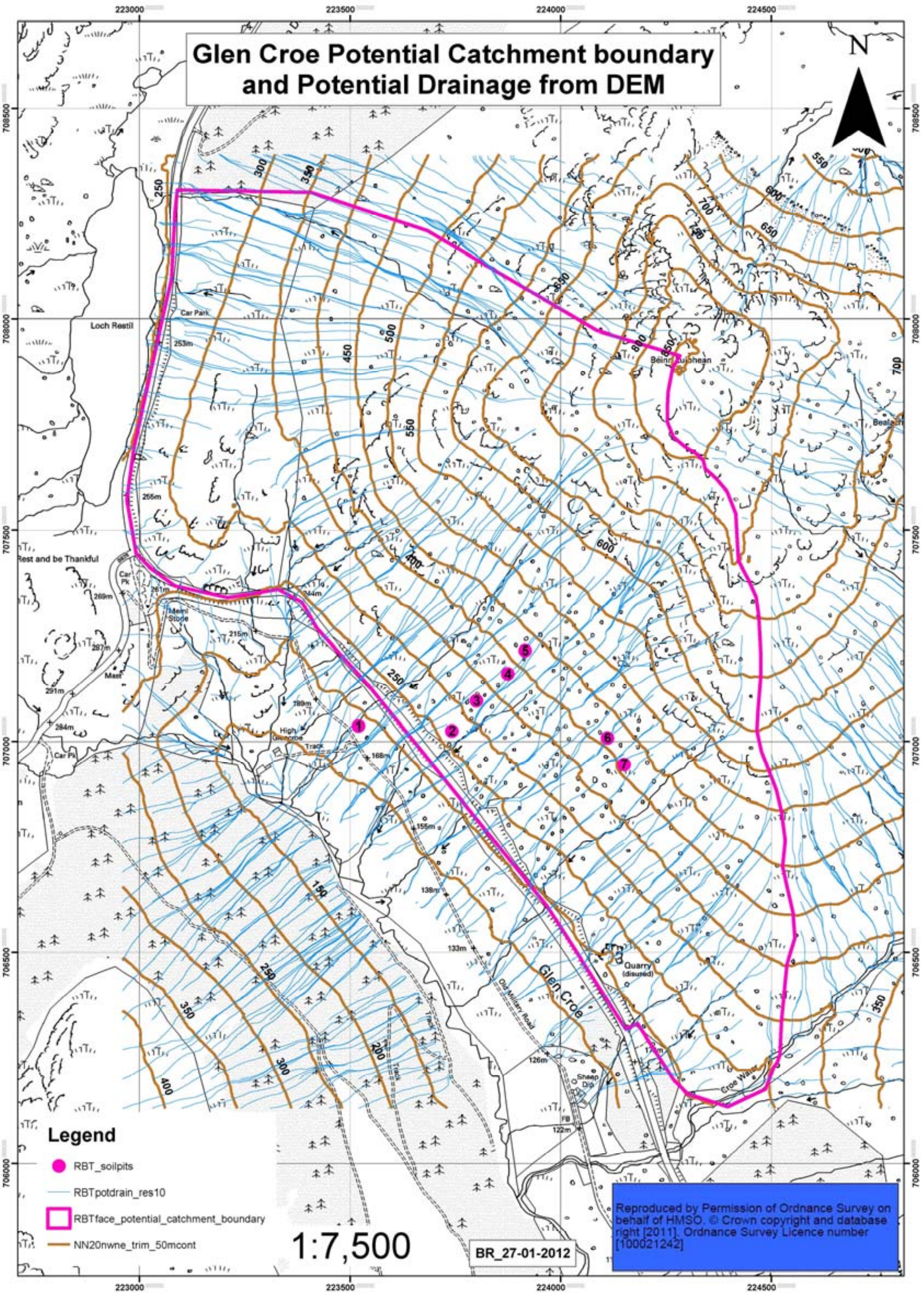
The border colour represents the Accumulated Temperature 5°C (AT5) range of the square.

The colours of the lines within the square represent its Moisture Deficit (MD) range.

The direction of the lines within the square represents the range of the Detailed Aspect Method of Scoring (DAMS) indicating the potential severity of site exposure. Lines with an alignment SW to NE representing the greatest exposure, whilst lines aligned N to S represent the least exposure.

The pink numbered dots indicate points on the hill where soil and site factors were assessed during our rapid reconnaissance.

Appendix 2.


Glen Croe Potential Catchment boundary
and Potential Drainage from DEM
N
Loch Restil
Car Park
Rest and be Thankful
Beinn Luibhean
Glen Croe
Quarry (disused)
Old Military Road
Croe Water
Legend
RBT_soilpits
RBTpotdrain_res10
RBTface_potential_catchment_boundary
NN20nwne_trim_50mcont
1:7,500
BR_27-01-2012
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223000
223500
224000
224500
708500
708000
707500
707000
706500
706000

Narrative for Appendix 2 map

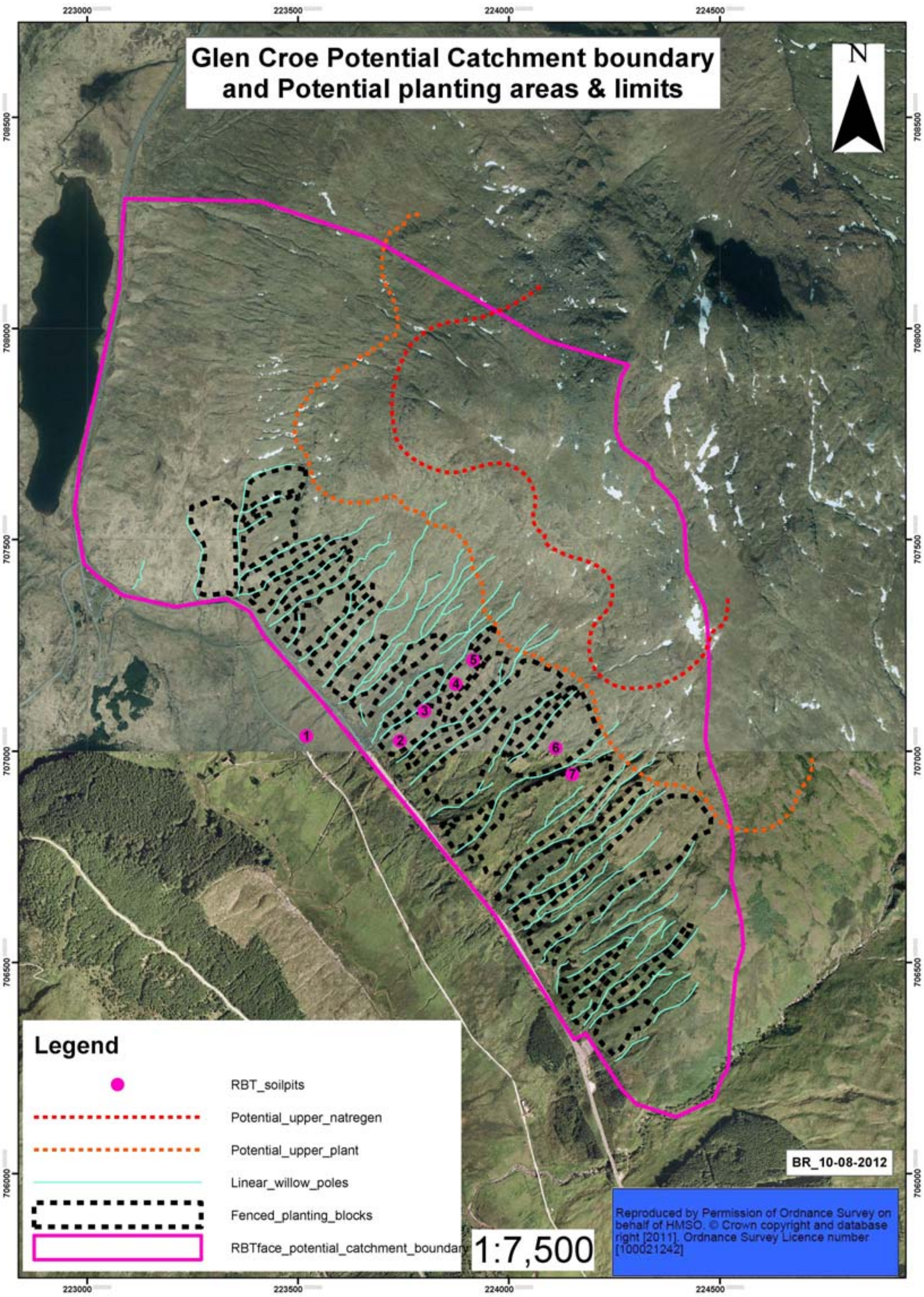
The pink bordered shape on the map defines the catchment, from which debris flows have the potential to directly affect the A83 ‘Rest and Be Thankful’ trunk road.

The brown lines across the map represent elevation contours at 50m intervals and their elevation above the OS Newlyn datum high water mark.

The blue lines are generated from Ordnance Survey, Digital Elevation Tiles (DET), in which 10m x 10m grid squares are allocated their elevation above the OS Newlyn datum high water mark in metres (m). A spatial GIS model is then applied to the OS DET and plots the direction of least resistance down the slope, along which water might flow and represent the potential drainage pattern, within the catchment area.

The pink numbered dots indicate points on the hill where soil and site factors were assessed during our rapid reconnaissance.

Appendix 3.


Glen Croe Potential Catchment boundary
and Potential planting areas & limits
N
Legend
RBT_soilpits
Potential_upper_natregen
Potential_upper_plant
Linear_willow_poles
Fenced_planting_blocks
RBTface_potential_catchment_boundary
1:7,500
BR_10-08-2012
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Narrative for Appendix 3 map

The pink bordered shape on the map defines the catchment, from which debris flows have the potential to directly affect the A83 ‘Rest and Be Thankful’ trunk road.

The red pecked line represents our “Potential upper natural regeneration” limit of shrubs and trees, having considered the climatic and edaphic conditions of the site and relying upon site enrichment by planting shrub and tree species at lower altitude to provide viable seed. This should not be taken as an absolute limit, as climatic and edaphic conditions, combined with time may change.

The orange pecked line represents our “Potential upper planting” limit, having considered the climatic and edaphic conditions of the site. This in our opinion is the extent to which planting shrubs and trees would prove successful and act as a dynamic aid to slope stabilisation, along with engineered measures adjacent to the A83.

The blue lines represent water courses, some of which have been interrupted by debris flows, where we think that by driving live willow poles into the soil and allowing them to root may enable the process of slope stabilisation to commence.

The black pecked enclosures represent potential areas from which grazing animals will need to be excluded by fencing. Care will be needed in the siting and construction of these enclosures, so that they are easily maintained and do not exacerbate the erosion of the hillside by concentrating animal movement into limited areas adjacent to watercourses.

The pink numbered dots indicate points on the hill where soil and site factors were assessed during our rapid reconnaissance.