Response to Recommended Preferred Route Corridor and Possible Route Options – March 2021 – A83 Access to Argyll and Bute

Introduction

The **Jacob**s ***A≡COM*** Consultation is referred to in this document as the Jacobs Assessment.

A. Primary Aim

To secure a safe and sustainable alternative to the present route of the A83(T) through Glen Croe.

B. Guiding Principles

The route should be free from threat of closure by landslips
The construction of the route should be completed with the least possible delay consistent with safety and long-term maintenance considerations Due consideration should be given to environmental impact.

C. Constraints

The topography and geology of Glen Croe
Weather conditions
Overall cost of construction and future maintenance
The impact during the construction of the new route on the existing A83(T) and the Old Military Road.

The Topographical Setting

Fig. 1 Glen Croe from the view point at the NW summit

Glen Croe is a glacial valley with an asymmetrical profile. The NE slopes (left hand side of fig. 1) rise steeply to the summit of Beinn Luibhean (859 m, Fig. 2) in a horizontal distance of 1·25 km; the heavily wooded ground on the opposite side of the glen ground rises somewhat less steeply towards gentler slopes above the tree line before rising again more steeply towards the summit ridge of Coire Culach (660 m) and the distant Ben Donich (847 m.) more than 2.4 km to the SW.

The upper part of the SW slopes of Beinn Luibhean (fig.2) are marked by craggy outcrops below which 500 m of largely uninterrupted mountainside, sparsely clad in vegetation, extend to the A83(T). These slopes, tilted at an average of 32˚, are exposed to the full effect of rainfall, driven by the prevailing SW winds. By contrast the slopes on the SE side of Glen Croe vary between about 20˚ and 22˚.

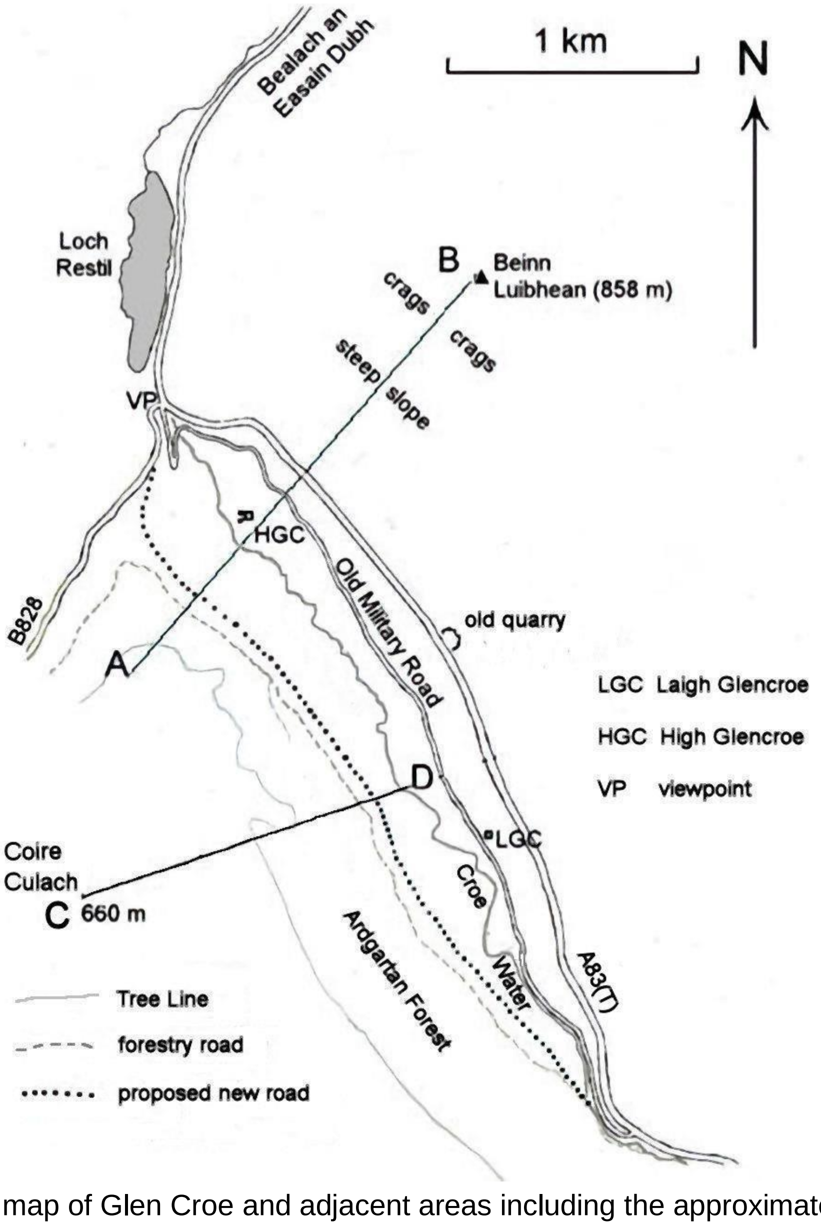

Fig. 2. Sketch map of Glen Croe and adjacent areas including the approximate position of an alternative safe route for the A83(T) along the SW slopes of Glen Croe.

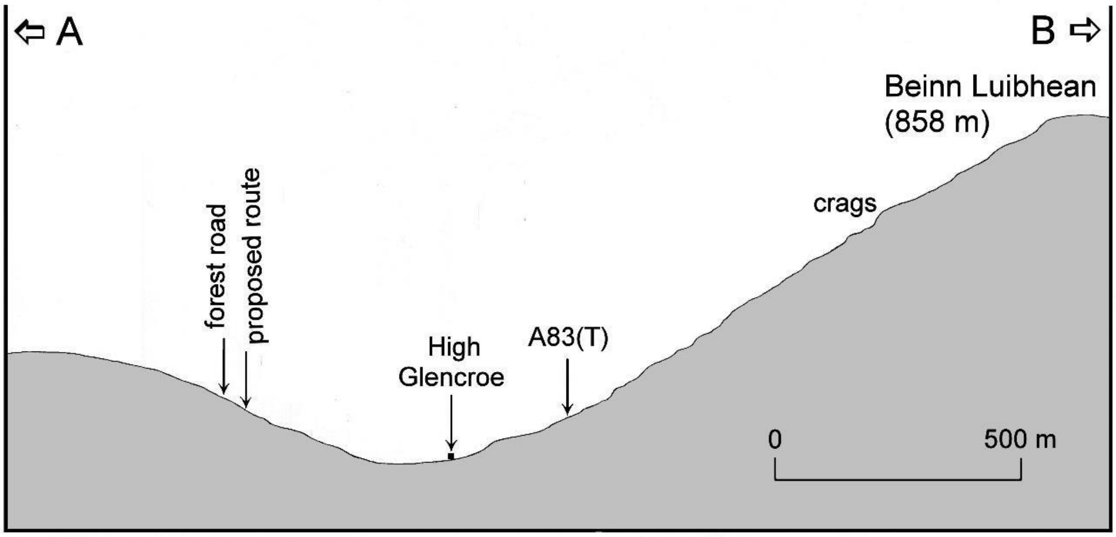

Fig. 3. Cross section of the upper part of Glen Croe (see fig. 2) based on the contours on OS Explorer map 364.

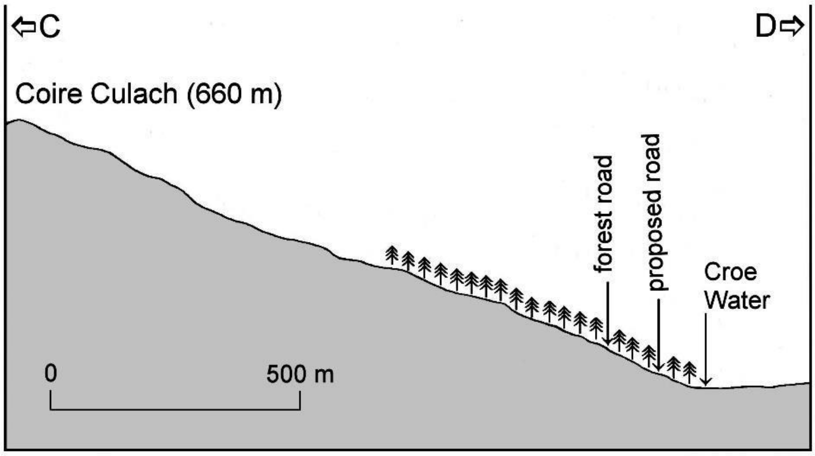

Fig. 4. Cross section of Glen Croe north of Laigh Glencroe based on the contours on OS Explorer map 364, at the same scale as fig.2.

Geology

The Bedrock

The principal bedrock of the area is the Beinn Bheula Schist, a unit of the Southern Highland Group of the Dalradian Supergroup in the Grampian Highlands (Stephenson, D. & Gould, D. 1996). These rocks originated as sediments, ranging in composition from coarse quartz-rich sands and grits to clay-rich mud, deposited as poorly sorted turbidites in a marine trench. During the Lower Palaeozoic Caledonian mountain-building episode, rocks of the SW Highlands were subjected to multiple deformations under conditions of raised shearing stress and increasing temperature and pressure resulting in extensive recrystallisation and the growth of new minerals.

Clay minerals, being chemically unstable at elevated temperature and pressure, were replaced by minerals of the mica group, first chlorite then at higher temperatures biotite. Under conditions of raised shearing stress these minerals grow with preferred orientation imparting a foliation or schistosity to the resulting metamorphic rock. Coarser grained beds, rich in quartz and subordinate feldspar and clay, were consolidated to form schistose-grits or quartzose schists; the finer-grained beds, initially richer in clay, were replaced by more strongly foliated rocks referred to as mica schist. The quartzose schists, with subordinate amounts of chlorite are generally more resistant to deformation, whereas the deformation of the chlorite schists has been greatly facilitated by slippage on the cleavage planes of the

Fig. 5. Deformed mica schist exposed in a cutting of the forestry road close to the junction with the Old Military Road in Glen Croe [NN 24458 04767]. Note the white vein quartz, deposited from aqueous fluids in areas of low stress during in homogeneous shearing stress (the diameter of lens cap scale 56 mm).

Fig.6. Quartzose schist cropping out beside the forest road [NN 23922 05413] about 1 km NNW of fig. 5. The lithology of this rock is dominated by quartz, subordinate feldspar and a smaller proportion of chlorite. The protolith of this rock would have been a poorly sorted coarse-grained muddy sandstone.

micaceous crystals (fig. 5). The scale and intensity of deformation of the Beinn Bheula Schists is highly variable due to the contrasting lithologies of the resistant beds of the quartzose schists (fig.6) and the more easily deformed mica schists.

Apart from foliation the Beinn Bheula Schist is extensively jointed. The joints can have resulted from fracturing of the more competent beds during the mountain-building episodes and or from arching of the Earth's crust during Postglacial isostatic uplift. Loci of structural weakness are associated with fault planes where there has been lateral slippage. The geological maps of the area record a number of faults, especially with NNE-SSW trends. The presence of structural trends and inhomogeneity in the bedrock has a bearing on the stability of superficial deposits and cuttings. They must also be taken into consideration in the context of tunnelling. In the vicinity of Glen Croe the dominant orientation of the foliation of the Beinn Bheula Schists is NE-SW, across the line of the glen but with variable dips, commonly towards the NW and with occasional flattening.

The bedrock is cut by a number of igneous intrusions some of which might be encountered during tunnelling and road construction. Lamprophyric dykes crops out in the vicinity of the view point at the head of Glen Croe. A more extensive igneous intrusion crops out at the abandoned quarry (fig. 2). This medium-grained pyroxene-mica-diorite extends to the NE, well away from the A83(T), but at its SW end, close to the trunk road, an igneous breccia of uncertain extent crops out on the line of the trunk road. It is possible that other unrecorded dykes exist, especially within the densely forested area on the SW side of the glen.

Unconsolidated Drift and its Stability

The slopes on both sides of Glen Croe are mantled by varying thickness of drift composed of varying proportions of regolith (loosely bound residual material produced by weathering of the bedrock), glaciogenic sediments and debris that has slipped down the slopes. Boulders of various sizes are perched on the slopes. They include fragments of bedrock (fig. 7) and erratics of various compositions and origins transported there by glacial action.

The stability of the drift is influenced by its composition, the steepness of the slopes and its content of water. In general, unconsolidated drift is critically unstable on slopes above about 46˚ but slippage will take place at much lower angles depending on the adherence of the particles (governed by shape, size and composition) and in particular by water content. The effect of water is inherently variable in the climate of the Argyll. Although the annual rainfall at Loch Restil exceeded 3,500 mm in recent years the daily average is highly variable. On 3rd May 2021, 47 mm was recorded and this was concentrated in short periods of great intensity. Argyll is not immune to periods of drought so the stability of drift is also influenced by the condition of the drift prior to heavy rainfall.

One of the results of global warming is that there has been an increase in the extremes of weather conditions. It would be safe to assume that this applies to Argyll as much as anywhere else and could explain the initiation of debris flows at the Rest and be Thankful many decades after the construction of the A83(T). It is widely acknowledged that plant roots play a vital role in the stabilisation of unconsolidated drift on hillsides. The sparse vegetation on the steep slopes above the trunk road is in great contrast with the densely forested slopes on the other side of the glen.

Fig. 7. Unconsolidated drift at the side of the forestry road [NN 24181 05089]: typical diamictite with a wide range of sizes and compositions of clasts. Note the large, angular fragment of white vein quartz beside the lens cap (diameter 56 mm) and the somewhat smaller clasts of metagreywacke.

Summary and comments regarding Route Options

Pink Route: A new single carriageway road approximately 4.1 km in length incorporating a tunnel about 2.9 km long emerging north of Loch Restil at Bealach an Easain Dubh.
Yellow Route: A new single carriageway road about 2.1 km in length including a raised viaduct 1.8 km in length supported on piers with a maximum height of 37 m
Brown Route: A debris flow shelter built over a 1.3 km section of the existing A73 to protect it from debris flows.
Purple Route: A new single carriage way about 3.2 km in length along the valley floor of Glen Croe entering a 1.2 km length of tunnel near High Glen Croe emerging north of Loch Restil.
Green Route: A new single carriage way route about 4.3 km in length along the SW slopes of Glen Croe.
The advantages and disadvantages of each of the above routes are listed in the Jacobs Assessment. Some general points are listed below:

1. It needs to be emphasised that the whole of the section of the A83(T) as illustrated in fig. 8 is at risk from further debris flows. The risk is particularly significant in the

context of the Yellow, Brown and Purple options during construction and maintenance.

2. The disruption of traffic flow during construction would not be confined to the immediate surroundings of the work but would also be affected by increased traffic during the transport of building materials and waste.

Fig. 8. The slopes of Beinn Leubhean above the A73(T) in Glen Croe. Note the scar (see arow) left by a recent landslip that closed both the main road and the Old Military Road. There is a risk of further landslips across the entire width illustrated, but especially from the slopes on the left-hand half side of the photograph.

3. The large quantities of reinforced concrete used in tunnelling, debris shelters and elevated viaducts will use correspondingly large amounts of cement the production of which creates excessive quantities of greenhouse gas (CO_2).

4. The cost of tunnelling is liable to have a disproportionate effect on the overall costs of the pink and purple routes. Tunnelling runs the risks of problems arising from the variable physical properties of the bedrock Beinn Bheula Schists and Caledonian intrusions.

5. While the green option avoids danger from the debris flows from the slopes of Beinn Luibhean the risk of debris flows on the slopes on the opposite side of Glen Croe has to be assessed.

The Setting for the Green Option

Of all the options listed in the Jacobs Assessment the Green Option includes the least number of disadvantages. These are commented on below.

1. The difficulty of carrying out construction on steep hillside, while obviously presenting challenges, can be no more serious than in some of the other options.
2. The issue regarding mitigation against landslide and debris flow hazard has to be seen in the context of the particular topographical and environmental conditions pertaining on the SW slopes of Glen Croe.
3. The close proximity of the top end of the green route to the view point is surely an advantage rather than a disadvantage, it depends on the design of the road and its connection to the B828 road to Lochgoilhead.
4. The impact of the Green Option on the woodland is a matter of management rather than a disadvantage as is explained below.

Slope Stability and Drainage on the Forestry Slopes

Access to the forest is already provided by a set of well-constructed dirt roads. This affords the opportunity to examine what effect they have had on slope stability. One such road (fig.9) is accessible from close to the southern end of the Old Military Road; it ascends from an altitude of about 100 m above mean sea level to about 280 m near the NW end of the glen. This road is wide enough to accommodate the large vehicles used to transport timber and there are a number of passing places.

Fig. 9. Forestry road at an altitude of about 200 m. on line of section C – D (figs 2 & 4)

i) The Sitka Spruce forest has the potential to profoundly stabilise the slopes. The network of interlapping roots of the densely planted trees holds the soil in place and a very high proportion of the rain that falls on the forest is absorbed and released to the atmosphere by transpiration reducing the build-up of pore pressure in the subsoil that might otherwise lead loss of cohesion and consequent slippage.

ii) Although the rainfall may differ little on either side of the glen the retention of groundwater must therefore be fundamentally different. Excess runoff produced during periods of heavy rainfall is intercepted by drains on the upslope side of the road. These connect with culverts that discharge on the down-side.

iii) Above 150 m the forestry road does not intersect major drainage channels but at lower altitudes there exist a number of boulder-choked gullies (Fig. 10). This reflects the extent of the catchment areas to the SW of the road. The catchment of the upper reaches of the road is limited by the position of the Coire Culach ridge; at lower levels gullies are fed by the much more extensive catchment situated between the road and Ben Donich. Nevertheless, the ground, up-slope from the lower end of the road, appears to be no less stable. The gullies, while channelling a greater volume of water, do not appear to be eroding the ground between them and the boulders show little evidence of instability. From their size it appears likely they were transported to their present positions at the time of last retreat of the ice when deglaciation took place some ten thousand years or so ago leading to a short episode of greatly enhanced flow of meltwater. Major excavation of the hillside has to take into account the danger that some of these boulder trails could collapse; it would be prudent to consider what localised remediation measures might be required.

Fig. 10. Boulder trail in a gully beside the lower reaches of the forestry road. The trail extends some metres to the left of the exposed boulders but is obscured by a thick mantle of mossy vegetation

Fig. 11. Rare collapse of an unusually thick deposit of unconsolidated drift. The large boulders were placed to protect the road from any further slippage.

iv) The only obvious sign of recent instability of unconsolidated drift on the up-slope side of the road is where an unusually thick layer of unconsolidated drift has collapsed (fig. 11).

v) Rock cuttings in general appear stable regardless of the variation of rock type. The foliation of the bed rock and the main joint directions are largely close to normal to the exposed rock faces. Trees close to the up-slope side of the road show little or no disturbance since they were planted (see the trees above the cutting on the righthand-side of Fig. 9). Spoil from the cuttings has been used in places to extend the width of the road. This has resulted in significant over-steepening on the down-slope side of the road. However, these over-steepened banks appear stable, apart from minor gullying caused by discharge from culverts.

vi) Crucially, the average slope of the hillside on the SW side of the Clen Croe is between about 20˚ and 22˚. This in itself is undoubtedly the most significant factor affecting the stability of the unconsolidated drift. Examination of satellite images of the treeless hillsides up-slope from the tree line of the Ardgartan Forest does not appear to reveal significant mass movement of the superficial deposits.

Conclusion

Taken together the above points provide a strong argument for choosing the Green Option for the new route up Glen Crow. Upgrading of the forestry road to provide a new route for the A83(T) looks attractive but may be less than ideal. Widening of the road would require strengthening of its steeply banked outer edges to cope with continuous use by heavy traffic. It might also lead to the destabilisation of boulder trails. In the longer term it might be wiser to construct a new road, roughly parallel to it but at a lower level.

A New Route for the A83(T)

Apart from fulfilling the aim and guiding principles outlined in the introduction, consideration has to be given to the practical issues that would arise from the construction of a new road along the SW slopes of Glen Croe. Account would also have to taken of the impact of such a project on the particular environment of the Ardgartan Forest and the management aims and objectives of Forestry Scotland. Wider economic and social effects, and opportunities created by the creation and management of the new road should not be ignored.

Construction of the New Route

The safe route up the SW side of Glen Croe (fig. 2) would be similar in length to the portion of the A83(T) that it replaced although it might be slightly longer. An average gradient of the road of about 5% could be maintained although the actual gradient at any point might vary depending on the constraints of topography. The speed and cost of construction would be affected by the geotechnical issues encountered and how they were dealt with.

The creation of the road bed would require excavation of the bedrock. The stability of the resultant cuttings would be influenced by the coherence, foliation and joint orientation and spacing, of the bedrock and any faults or intrusions encountered (Eddleston, M. *et al*. 1995).

The orientation of these structures would appear to favour pre-split cuttings with a steep batter thus minimising the amount of rock waste to be removed. The condition of the foliation and jointing also appears to be such that bolting and provision of a catchment ditch for falling debris might not be necessary.

Regarding drainage, the presence of the existing forestry road some tens of metres up-slope intersects run-off from higher levels but drainage channels from the forestry-road culverts would require hardening to avoid erosion of the slope above the new road. Run-off reaching the new road would be directed via carriage-way drains into the river below.

The lowermost third of the route encounters hillslopes significantly less steeply than the average indicated by the section C-D (fig. 4) and could therefore expect to present the lesser construction challenges. Boulder trails from the gullies cut by the forestry road may require stabilisation. Parts of the slope at an altitude between 150 to 200 m opposite Laigh Glencroe are clear of forest but beyond that the tree cover is denser so it is not possible, without a ground survey, to determine where it might be necessary to support the outer parts of the carriageway on revetments anchored in the bedrock. The top of the route (fig. 12) is clear of forest including an area that has been clear-felled recently. A steady gradient could be maintained here by routing the carriageway along a wide curve, following the contours as much as possible but incorporating a short length of viaduct or a bridge to allow for drainage. The road might connect with the B828 as shown here or with the topmost part of the Old Military Road. Some straightening of the connection with the A83(T) in the vicinity of the Rest and be Thankful Viewpoint would be desirable but would add to the cost of the project.

Fig. 12. View from a knoll [NN 22890 07220] overlooking the B828, 240 m. SW of the junction with the A83(T) at the Rest and be Thankful. A possible route for the upper end of a new road up the SW side of Glen Croe, is pasted in. The new road would enter the forest at a bench in the slope at A, some tens of metres below the forest road. A safer connection with the B828 could perhaps be made at a junction near B.

Maintenance of the new route

The long-term safety of the new route would depend to a significant extent on the condition of the forest which is under the management of Scottish Forests. Consultation with this agency would be needed to ensure that agreement could be reached that future management of the forest would take account of the role that it plays in slope stability. This would require that clear felling should be avoided although selective thinning could take place provided it was combined with replacement with native species, much in accord with the environmental policies already adopted by the government agency. Ideally management of the new road should be considered as a joint arrangement shared by Scottish Forests and Transport Scotland to ensure that the safety of the road would be monitored continuously by staff based in the area to ensure that drains, culverts and other protections would be maintained.

The building of a new road could be achieved with minimal impact on access to the Ardgartan Forest for walkers. An aspect of the maintenance should include the upkeep of the safe condition of the existing forest road as it affords a measure of extra protection of the new road below it from the effects of future extreme weather events.

The next step

In view of the ongoing threat to the economy of Argyll and the safety of road users a detailed 'boots on ground' survey of a possible route for the A83 along the SW slope of Glen Croe should be undertaken without further delay.

References

Eddleston, M. Walthall, S., Cripps, J.C., Culshaw, M.G. 1995. *Engineerig Geology of Construction.* Geological Society Special Publication No 10, pp 173-182.

Stephenson, D. & Gould, D. 1996. *British regional geology: the Grampian Highlands*. (4th edition). London: HMSO for the British Geological Survey.

British Geological Survey 1:50 000 Series Sheets
Loch Lomond, Scotland Sheet 38W
Loch Goilhead, Scotland Sheet 37E

Ordnance Survey 1:25 000 scale Explorer sheet 364, Loch Lomond North

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James G MacDonald
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