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The A83 Loch Shira landslide, Scotland

Le glissement de terrain A83 du Loch Shira, en Écosse

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ABSTRACT: The A83 Loch Shira landslide has been active since the early-1990s, and this paper will present a brief history of this mass movement. Significant movements are evident in the bund immediately adjacent to the road, narrowing the verge from around 2m in 1995 to effectively zero in places. Movement is also apparent in the cut slope above the bund and evidenced clearly by the significant distortion of a catch pit, the date of installation of which, while post-1995, is unknown. The movement of the landslide is driven by groundwater, specifically water from rockhead at the interface with the superficial deposits. This drives movement downslope to the stiffer complex formed by a retaining wall, the road and the rockfill bund adjacent to the road. In 1995 it was postulated that this stiffer complex could store energy and potentially lead to a catastrophic failure. The movement of the bund and the cut slope above seems likely to be a manifestation of a limited pressure (or energy) release and the current state of the landslide is of concern. The potential adverse influences of climate change on the landslide include increased water in the system from both direct rainfall and recharged groundwater, storm effects on the retaining wall and erosion of the slope above the retaining wall from increased road runoff.

RÉSUMÉ: Le glissement de terrain A83 du Loch Shira est actif depuis le début des années 1990, et cet article présentera un bref historique de ce mouvement de masse. Des mouvements importants sont évidents dans la digue immédiatement adjacente à la route, rétrécissant l'accotement d'environ 2 m en 1995 à effectivement zéro par endroits. Le mouvement est également apparent dans la pente coupée au-dessus de la digue et mis en évidence par la déformation importante d'un puisard dont la date d'installation, bien que postérieure à 1995, est inconnue. Le mouvement du glissement de terrain est entraîné par les eaux souterraines, en particulier l'eau de la tête rocheuse à l'interface avec les dépôts superficiels. Cela entraîne un mouvement vers le bas de la pente vers le complexe plus rigide formé par un mur de soutènement, la route et la digue en enrochement adjacente à la route. En 1995, il a été postulé que ce complexe plus rigide pourrait stocker de l'énergie et potentiellement conduire à une défaillance catastrophique. Le mouvement de la digue et de la pente de coupe au-dessus semble être la manifestation d'une libération de pression (ou d'énergie) limitée et l'état actuel du glissement de terrain est préoccupant. Les influences négatives potentielles du changement climatique sur le glissement de terrain comprennent l'augmentation de l'eau dans le système à partir des précipitations directes et des eaux souterraines rechargées, les effets des tempêtes sur le mur de soutènement et l'érosion de la pente au-dessus du mur de soutènement due à l'augmentation du ruissellement routier.

Keywords: Landslide; instability; drainage road; infrastructure.

1 INTRODUCTION

Loch Shira is located approximately 65 km to the northwest of Glasgow (Figure 1) and the A83 trunk (strategic) road to mid-Argyll follows its shoreline on the approach to Inverary.

Since the earliest history of the landslide in the 1970s, only relatively minor works have been undertaken to reduce instability. The site was highlighted as high risk in the Scottish Road Network Landslides Study (Winter et al., 2005, 2008, 2013).

In this paper we examine the history of the landslide and indicate the likely approach to remediation.

2 HISTORY

In the mid-1970s a 1 m high masonry retaining wall that showed signs of distress was removed and the toe of the slope cut back. Soon after, what was described as a major slip occurred and, following emergency works to clear the road, a 2m high gabion basket wall was installed with rockfill behind.

In 1992 the stability of the gabion basket wall was questioned. The wall showed signs of bulging, the baskets were rounded in shape and the fill seemed to be loose. There was no evidence of any compromise to the overall stability of the wall.

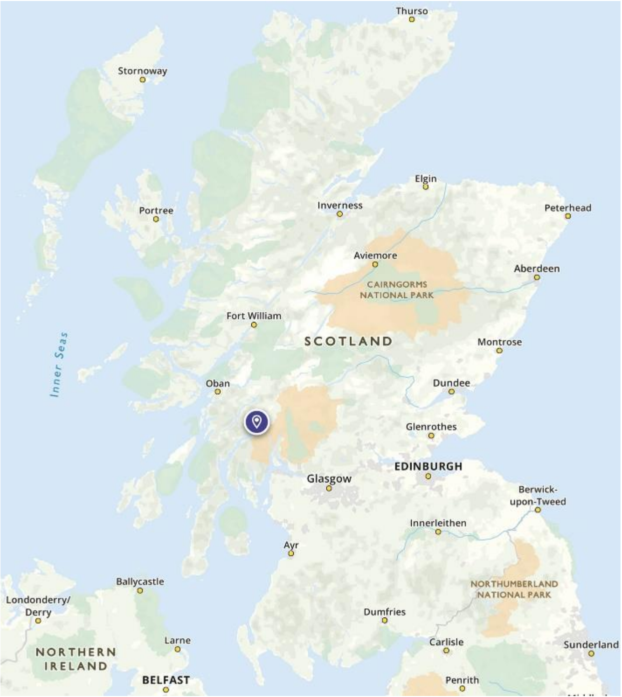

Figure . Map of Scotland (excluding Orkney and Shetland) showing the location of the Loch Shira landslide.

At this time the slope was inspected and multiple shallow slip circles and scarps up to 300 mm in height identified. Trees with vertical trunks of 3 m to 5 m height were [erroneously] cited as evidence of a lack of movement. Monitoring pins were established on the road, the top of the wall and on the slope; no movement of the pins was recorded between December 1992 and March 1994.

In April 1994, 15 mm to 20 mm of rotational movement was recorded [it remains unclear how this was determined to be rotational movement]. An emergency contract was let to remove the gabion wall and trim the cut slope to 1:2. During the contract there was a slope failure at the southern end of the works and remedial works were extended 20 m in this direction. Movement began at the northern end of the works and a 0.5 m rockfill blanket was installed at the toe of the cut slope. The contract was completed in June 1994 and the surface of the cut slope left exposed to allow visual detection of water flow. In September 1994 slope filter drains were installed and a minor slope failure repaired.

In December 1994, exceptionally heavy rainfall caused two minor slips above the surface water cut-off drain at the top of the cut slope. Further emergency works were carried out to repair the drainage system and to install a 6 m high rockfill bund extending 80 m along the toe of the slope. During these works extensive cracking was observed in the area above the cut slope. Extensive monitoring using wooden surface pegs was established and this minor downslope movement over the next six to 12 months.

Contemporaneous, local rainfall data is not available. The nearest current gauge is at Loch Restil which gives an average annual rainfall for 2013 to 2022 of 3,341 mm with a range of 2,613 to 4,110 mm. However, the distance (approximately 12 km) from and relative elevation (around 250 m higher) of this gauge to Loch Shira does perhaps question whether this is entirely representative. In addition, Inverary is anecdotally known for having something of a microclimate with unverified sources suggesting annual average rainfall closer to 1,600 mm.

In April 1995, the first author and a colleague undertook an assessment of the slope (Figure 2). The primary conclusion of that work was that the failure was most likely controlled by water pressure at rockhead. Both old and new scarps were identified, recent slips in the regraded cut slope were observed and the entire area of the landslide was wet with some areas being identified as particularly boggy. Streams, both active and ephemeral were encountered, some of which fed into tension cracks and/or scarps. Other slips were identified in the area outside the landslide as might be expected.

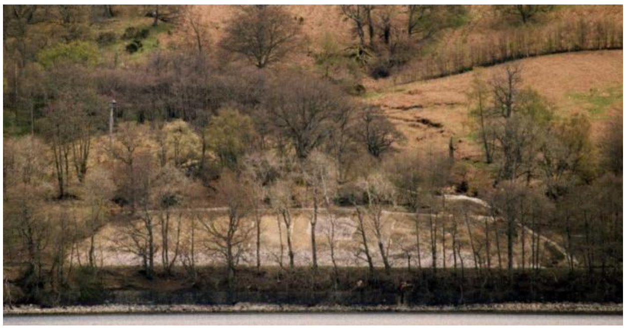

Figure 2. The Loch Shira landslide in 1995.

The depth to the Phyllite rockhead (Anon., 1897; Hill et al., 1905) at road level was, to some degree, uncertain (see Figure 3) and fundamental to the likely behaviour of the landslide. While only minor movements had been observed since the December 1994 rainfall, it was considered that further such rainfall could initiate further significant movement. The prevalence of an extensive network of drainage ditches talking water from a former forestry plantation to the head of the landslide and the removal of the trees were considered to be contributory factors. A full ground investigation was recommended and designed and supervised in summer 1995 by the first author.

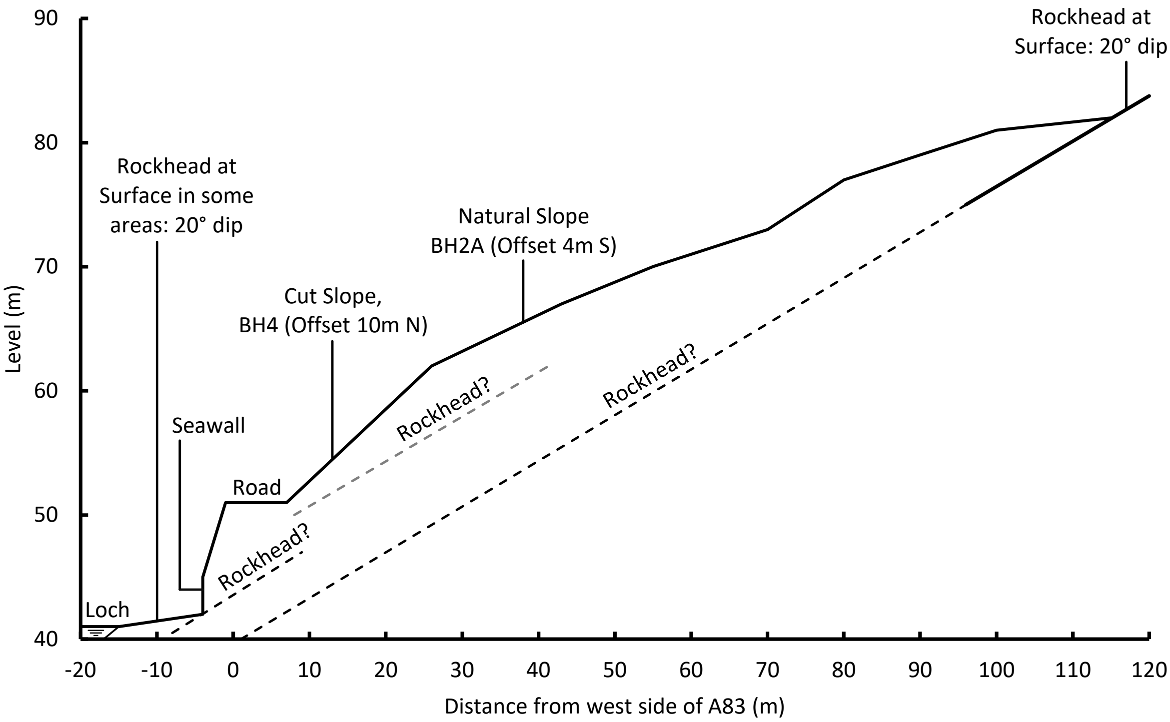

Figure 3. East-west section through the Loch Shira slope: the landslide is approximately 100m at road level.

The investigation comprised 10 boreholes sunk primarily by cable percussion, although four were sunk into bedrock by rotary drilling, and eight trial pits were sunk to depths of between 2.8 and 5.2 m with the extensive use of benching and trench support. Fifteen standpipe piezometers were installed (11 single installations and two twin installations) in the boreholes and trial pits to enable the long-term monitoring of groundwater; inclinometer tubes were installed in boreholes at the outer edge of the road to allow the long-term monitoring of subsurface lateral displacements.

The piezometer in the centre of the landslide regularly exhibited hydrostatic pressures in excess of 2.5 m above ground level. This broadly confirmed the hypothesis that high water pressures at the soil-rock interface were a major cause of instability.

Rockhead was originally conjectured in three locations but the ground invcestigation conformed the deeper location with daylighting at the loch shore.

3 RECENT CONDITION

Following the ground investigation, a remedial design was developed to stabilise the landslide. This involved the removal of ground water and the effective capture of surface water in order to reduce the water content of the soils and increase their strength and therefore the stability of the landslide mass. The design comprised:

- A pattern of downslope drainage on the natural slope consisting of well points to access water entering the landslide linked by a series of deep, lined rockfill trench drains linked to an external drainage system alternating with less deep, lined rockfill trench drains (without well points) on the body of the landslide with adjacent trench drains linked by herringbone drains.
- On the cut slope a system of counterfort drains linked by herringbone drains was proposed.

This preliminary design was not taken forward and there followed a period of almost two decades of irregular inspections which revealed relatively little movement at road level other than a significant degree of distortion to the rockfill bund immediately above the road. This occurred post-1998 when the first author's observations indicate that the rockfill bund remained planar, while by mid-1999 a sinusoidal shape could be observed along its length.

In the early-2010s the inspections recognised that the existing post-1995 drainage provision was in poor condition, effectively failed, and key elements of the drainage system were replaced, and additional drains installed to supplement the existing design in early-2016.

In 2022 (14 April, 18 and 26 October) the site was inspected by the authors as part of Transport Scotland's Vulnerable Locations Operations Group activities, which inter alia include identifying assets that need adaptation to provide adequate resilience to the effects of climate change. It was immediately apparent that there had been significant outward movement of the rockfill bund (Figure 4); as late as 1999 the distance from the toe to the edge of the running surface was 2m whereas by 2022 the bund was, in places, touching the edge of the running surface.

Inspection of the 2016 drainage scheme revealed measured strains of up to 15% in the downslope direction and up to 10% orthogonally (Figure 5).

Figure 4. The original distance of the toe of the bund from the edge line of the carriageway was approximately 2m, by April 2022 the distance had reduced to zero in places.

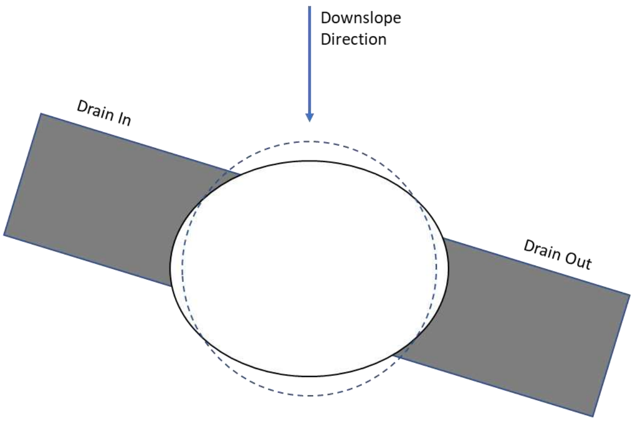

Figure 5. Catch pit plan view showing the original circular shape (600mm diameter, dashed blue line) the current shape of the ellipse (minor axis 510mm, major axis 660mm as a solid black line), the inflow and outflow pipes, and the downslope direction.

4 WAY FORWARD AND CONCLUSIONS

The A83 Loch Shira landslide has been of concern for around three decades.

Recent observations suggest that significant downslope movement is occurring within the landslide mass and that this is manifesting at road level in downslope movement and distortion of the rockfill bund. The major concern is that if the movements are occurring at rockhead then energy is being stored behind the mass formed by the seawall, the road and the slope between, leading to the potential for a brittle failure of those components.

The existing design is heavily predicated towards the use of deep and surface drains to capture groundwater and surface water, as would be expected for a landslide such as that at Loch Shira that is driven by water. These in turn rely on filter drains, including counterfort, herringbone and deep well points and trench drains. Recent work on the longevity of such drains (Nettleton et al., 2022) strongly suggest that significant maintenance of such drains, amounting to renewal of the filtration and drainage media, would be required approximately every 15 to 25 years. This is supported by the fact that the drains installed in the early-1990s had failed and were replaced and supplement in 2016, slightly more than 20 years after installation.

A review of potential remedial solutions is currently underway, but it is difficult to envisage a solution that does not involve large scale drainage features.

ACKNOWLEDGEMENTS

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