RAIB

Rail Accident Investigation Branch

Rail Accident Report

Landslip and derailment at Loch Eilt, north-west Scotland
22 January 2018

Report 10/2018
August 2018

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where the RAIB has described a factor as being linked to cause and the term is unqualified, this means that the RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident. However, where the RAIB is less confident about the existence of a factor, or its role in the causation of the accident, the RAIB will qualify its findings by use of the words 'probable' or 'possible', as appropriate. Where there is more than one potential explanation the RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, the words 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the event being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of the RAIB, expressed with the sole purpose of improving railway safety.

The RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Landslip and derailment at Loch Eilt, north-west Scotland, 22 January 2018

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Summary

Before dawn on Monday 22 January 2018, a passenger train travelling between Mallaig and Fort William in north-west Scotland struck a large landslip on a remote section of line near Glenfinnan. The leading coach of the 2-car train derailed to the left and came to a halt embedded in landslip debris. There were no injuries, but some diesel fuel escaped from the damaged train and was carried by flowing water into a lineside drainage channel. Due to the inaccessibility of the site, pollution control measures were not put in place until later the following day, and by this time some diesel fuel had entered nearby Loch Eilt.

The landslip originated from a natural hillside above the railway and was triggered by a combination of rainfall and snow melting during a rapid thaw. The ground may have been saturated before it froze. A protective fence, which had previously been installed near the railway to trap falling rocks was overwhelmed by the event.

The RAIB found that Network Rail's processes for managing landslip risk did not take account of the hazard caused by rapidly melting snow. It is unlikely that a greater understanding of snowmelt risk would have avoided the accident at Loch Eilt, but it could avoid or mitigate an accident in other circumstances.

The RAIB has made one recommendation to Network Rail to promote the development of weather forecasting processes to take account of risk due to snowmelt and ground thaw. The RAIB has also made one learning point concerning the importance of having effective and verified arrangements in place for responding to environmental emergencies in remote and inaccessible areas.

Introduction

Key definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 References to left and right refer to the train's direction of travel when the accident occurred. Loch Eilt was on the left-hand side of the train in its direction of travel.

3 Sources of evidence used in the investigation are listed in Appendix A.

The accident

Summary of the accident

4 At about 06:42 hrs on Monday 22 January 2018, the 06:03 hrs Mallaig to Glasgow Queen Street service, reporting number 1Y42, collided with debris from a landslip blocking the line. The train was travelling at about 40 mph (64 km/h) on the single line between Lochailort and Glenfinnan (figures 1 and 2).

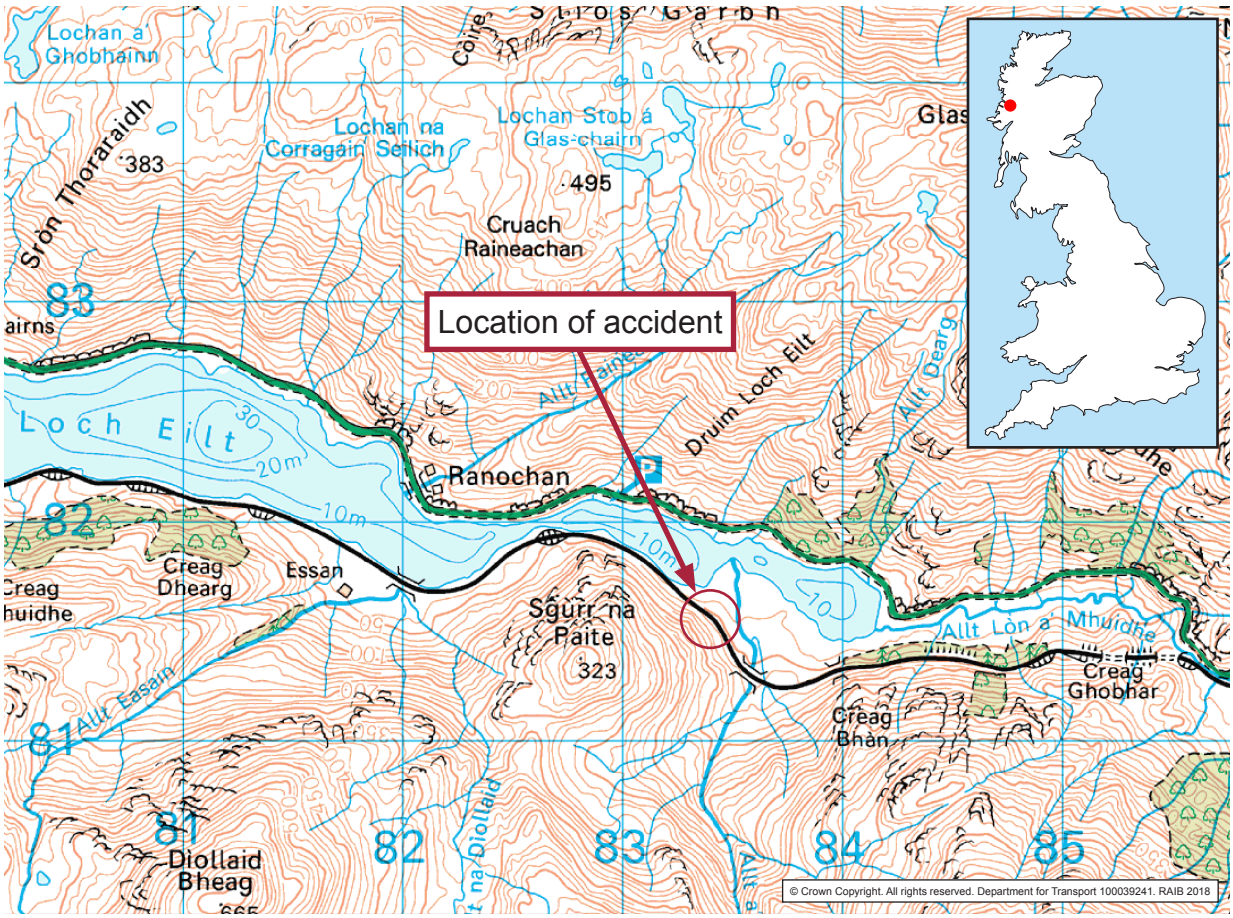

Figure 1: Ordnance Survey map showing location of accident

5 The train travelled through the debris for about 30 metres before coming to a stand with the leading vehicle derailed and tilted to the left (figures 3 and 4). After it stopped, the leading vehicle continued to shudder and was evacuated. There were no injuries to the traincrew or passengers.

6 The 2-carriage train was damaged and partly submerged in mud and flowing water. An estimated 700 litres of diesel fuel leaked from the damaged leading vehicle. Some diesel was carried by flowing water into the lineside drainage channel and entered Loch Eilt.

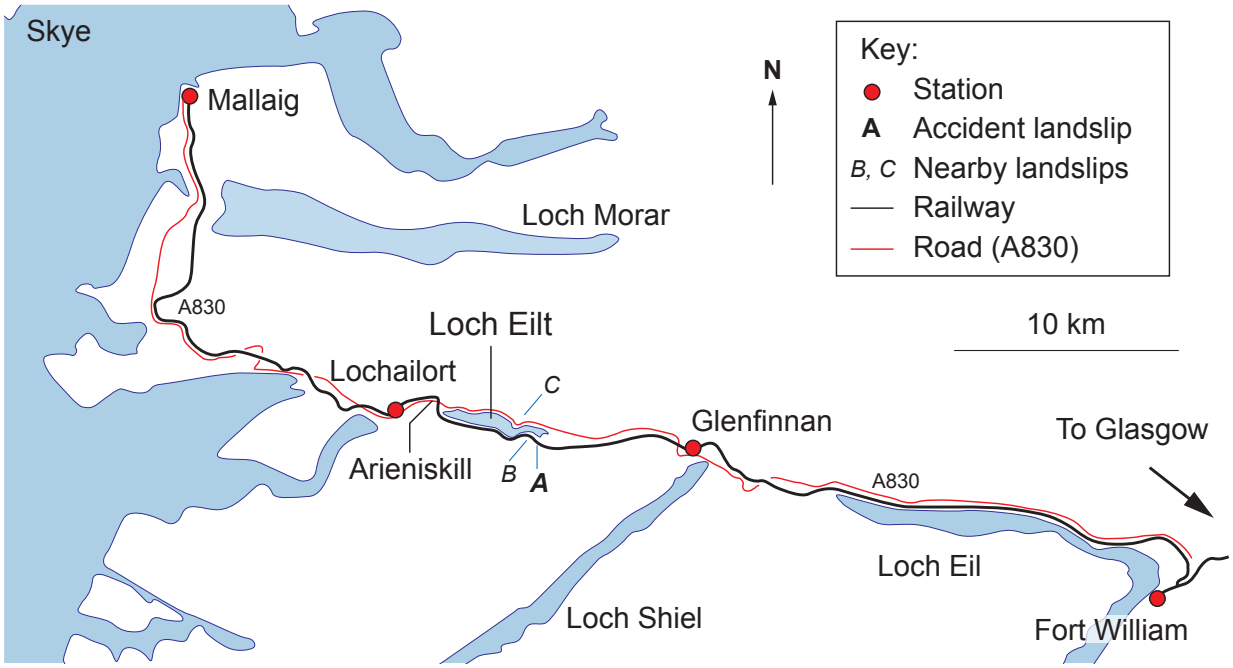

Figure 2: Map showing railway between Mallaig and Fort William and location of recent landslips. Sites marked 'B' and 'C' are refered to in paragraphs 54 and 41 respectively. Some intermediate stations have been omitted for clarity.

Figure 3: Front view of derailed train. Another recent landslip is visible in the distance on the opposite side of Loch Eilt (marked 'C').

Figure 4: Aerial view of landslip

Context

Location

7 The accident occurred at about 19 miles 200 yards[1] on a right-hand bend on a remote section of single line about five miles west of Glenfinnan. The railway at this location is in a shallow cutting on sloping ground, and runs along the south shore of Loch Eilt at an elevation of approximately 50 metres above sea level (figure 5). The route forms part of the West Highland line between Glasgow and Mallaig in the Scottish Highlands.

8 The landslip originated on a natural slope outside the railway boundary, about 80 metres outside the railway boundary fence, and 46 metres above track level, on the north-east sloping hillside of Sgùrr na Paite.

9 A slope protection project to reduce the risk to the railway in this area from rock falls, loose boulders and minor landslips was completed in 2017. This protection extended along a 5 mile section of track, included a catch-fence at the accident site intended to protect the railway from these hazards.

10 The track was non-electrified and controlled by a signaller located at Banavie North signal box near Fort William using the Radio Electronic Token Block (RETB) system.

[1] Mileage measured from Banavie near Fort William.

Figure 5: Aerial view showing proximity of the accident site to Loch Eilt

Organisations involved

11 Network Rail's Scotland Route was the owner and maintainer of the railway infrastructure and the employer of the civil engineers responsible for inspection and maintenance of the infrastructure.

12 Fairhurst, a structural and civil engineering consultancy, was employed by Scotland Route as a specialist geotechnical consultant and was the designer of the slope protection project (paragraph 54).

13 Amey plc (Amey) was employed by Network Rail to provide the staff who undertook the earthworks examinations at the accident site.

14 Mitie Waste & Environmental Services Limited (Mitie) was Network Rail's pollution services contractor, responsible for providing decontamination services following a chemical, oil or fuel spill. During this incident, Mitie deployed a specialist sub-contractor to the accident site.

15 Abellio Scotrail, trading as Scotrail, operated the train involved in the accident and most passenger services using the Fort William to Mallaig line. It was the employer of the driver and conductor.

16 The above parties freely co-operated with the investigation.

Train involved

17 Train 1Y42 was formed of a 2-carriage class 156 diesel multiple unit, number 156458. This was the first service of the day and was carrying five passengers and two crew.

Rail equipment/systems involved

18 The single bi-directional line had a maximum permitted speed of 40 mph (64 km/h). It was constructed of bull-head rail on wooden sleepers with a check rail[2] on the right-hand side due to curvature. At the site of the landslip, the gradient was rising at 1 in 48 in the direction of travel.

19 An open channel on the right-hand side of the line provided track drainage. This flowed west from the derailment site discharging into a stream flowing into Loch Eilt.

Staff involved

20 The driver and conductor were based at Mallaig depot and both had more than ten years' experience.

External circumstances

21 The accident occurred in darkness during mild and wet weather, shortly after a cold, snowy period.

[2] A rail or other special section provided alongside a running rail to give guidance to flanged wheels by restricting lateral movement of the wheels.

The sequence of events

Events preceding the accident

22 Following several days of very cold weather, a rise in temperature caused snow on the slopes above Loch Eilt to melt and the ground to thaw. This combined with rainfall to saturate the ground and trigger a landslip sometime between the previous train which passed at 23:50 hrs on Sunday 21 January and the accident at 06:42 hrs on Monday 22 January.

23 Train 1Y42 was the first train to use this section of line in either direction on 22 January. The service was running on time and was scheduled to call at Glenfinnan, five miles east of the accident site at 06:50 hrs.

Events during the accident

24 At 06:42 hrs, train 1Y42 approached the site of the landslip in darkness. The on-train data recorder indicates that train was travelling at around the 40 mph line speed when the train's brake was applied two seconds before the collision. Allowing for the driver's reaction time, this suggests that debris first came into the driver's view about four seconds before impact. Images from the train's forward facing CCTV camera show that the debris was not illuminated up by the train's headlight until around this time because of curvature of the track (figure 6).

Figure 6: Image from forward-facing CCTV camera on train 1Y42 before the collision showing debris ahead and patches of snow at track level. The left-hand rail is visible, but the view of the right-hand rail is obstructed.

25 The train continued for about 30 metres through the debris before stopping. The driver reported feeling impacts with boulders under the train. The leading vehicle of the two-carriage train derailed and tilted to the left.

Events following the accident

26 After the train came to rest tilting to the left, the driver felt the leading vehicle shudder and move and was concerned that the carriage could overturn.

27 The driver contacted the signaller to report the accident. The guard walked forwards from the rear cab to check on the driver and the one passenger in the leading coach. He assisted the driver and that one passenger to evacuate to the rear vehicle to await rescue with the other four passengers.

28 A rescue team arrived on site at 08:35 hrs. The passengers and crew were subsequently evacuated using a road-rail transport vehicle to Arieniskill at the western end of Loch Eilt, a distance of over 5 km (3 miles) where the railway can be accessed from the adjacent A830 road. They were collected from here by taxi.

29 Initial pollution control measures were put in place from the afternoon of Tuesday 23 January to control a leak of diesel fuel from the train which had entered the loch. More comprehensive pollution control measures were put in place in and around the loch from the following day.

30 The train was dug out over several days and removed from site. After further works to remove debris and stabilise the site, the line was reopened on the evening of Sunday 28 January after a closure of nearly seven days.

Key facts and analysis

Identification of the immediate cause

31 **Train 1Y42 collided with a landslip while travelling at a speed of around 40 mph (64 km/h).**

32 The driver of train 1Y42 was unaware of debris obstructing the track until about four seconds before impact. Prior to this, the debris was hidden by a curve and darkness. The driver applied the brake but could not avoid the collision.

Identification of causal factors

33 The accident occurred due to a combination of the following causal factors:

- landslip debris obstructed the line as a result of weather conditions that combined to increase the risk of slope instability (paragraph 34); and
- Network Rail was not aware of the landslip before train 1Y42 arrived at it (paragraph 59).

These factors are now considered in turn.

34 **Landslip debris obstructed the line as a result of weather conditions that combined to increase the risk of slope instability.**

Weather conditions

35 Following the accident, Network Rail's weather forecasting service (provided by an external specialist organisation) reviewed weather conditions relevant to the accident. It concluded that the landslip occurred during a thaw period, immediately after a very cold spell of weather. The review noted that the weather in north-west Scotland had been unusually wet during early January, and that soils were generally saturated. This was followed by several days of snow showers and sub-zero temperatures between 18 January and 20 January. It also noted that, at the end of this period, nearby road weather station data showed that the ground was widely frozen to depths of around 30 cm.

36 The RAIB has confirmed that snow cover extended over north-west Scotland by 20 January using satellite imagery (figure 7). Confirmation that this extended over the north slope of Sgùrr na Paite, to below track level, is provided by a witness report provided to the RAIB by a member of railway staff who arrived at the site a few hours after the accident.

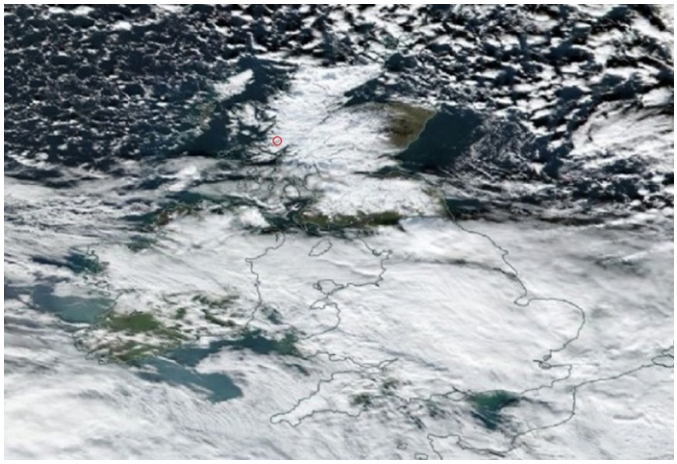

Figure 7: Satellite photograph showing snow cover across north-west Scotland on 20 January 2018. Note that England and Wales are covered in cloud (image copyright NASA Worldview)

37 Network Rail's weather service provider issued daily forecasts to Scotland Route's control centre early each morning, covering the following five days. The control centre distributed this information within the route at approximately 06:00 hrs each day. A summary of the weather hazards for each geographical areas was presented in a table with coloured cells showing the status of various weather parameters including wind, heavy rain, snow, frost, temperature and temperature range. The colour code used ranged from green (normal), through to yellow, amber and red (extreme), based on pre-determined threshold values. The table did not include numerical values except for temperature, which was given in degrees Celsius. If the forecast warned of an extreme weather event (normally indicated by one or more red cells), the extreme weather action teleconference (EWAT) process would be invoked as required by Network Rail standard NR/L2/OCS/021.

38 For the 24 hour period from 06:00 hrs on 21 January, the forecast for the Highland area (figure 8) gave the following information. For the heavy rain category, the cell was coloured green indicating that less than 30 mm was predicted. For minimum temperature, the cell was coloured red as a low of -7°C was predicted. However, for temperature range, the cell was coloured green as the predicted rise from -7°C to +1°C was less than the threshold value. A temperature change of 13°C was required to trigger a yellow 'be aware' warning. As temperatures were rising from lower values on previous days, there was no requirement for the EWAT process to be invoked.

Summary Hazards - Highland (Scotland)

Day (0600 to 0600)	Wind		Heavy Rain		Snow		Frost		Min Temp Morn (06-11)	Max Temp (06-18)	Min Temp (18-06)	Temp Range	
	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.				Hazard	Conf.
Sun	Aware	Low		High	Adverse	Medium	Adverse	High	-7.0	0.5	-4.0		High
Mon		High		High		High		Low	1.0	5.5	1.0		High
Tue	Adverse	Low	Extreme	Low		High	Aware	Low	2.5	6.5	0.0		High
Wed	Adverse	Low	Adverse	Low		High	Aware	Low	0.5	6.5	-0.5		High
Thu		High		High		High	Adverse	Medium	0.0	5.0	-6.5		High

Figure 8: Extract from five day weather forecast (hazards summary table) for 21-25 January 2018 covering the Highland area (Network Rail weather service)

39 The temperature rise during the 24 hour period from 06:00 hrs on 21 January was recorded by several personal weather stations[3] in the Fort William area, the closest around 20 km from the accident site[4]. Over this period, the recorded temperature near Fort William, which is at sea level and therefore likely to be slightly warmer, increased from -3°C to +6°C. The same sites recorded up to 31 mm of rain during the 24 hour period, most of which fell overnight on 21-22 January.

40 The combination of rainfall, snowmelt and ground thaw resulted in substantial amounts of water running down the hillside. This high risk event was not apparent from the forecast because Network Rail's specification for the hazards summary did not include a requirement to consider possible snowmelt and/or water released by thawing ground (see Observation, paragraph 69).

41 Network Rail geotechnical staff attending the accident site on 23 January observed that another landslip had occurred, 1 km to the north-west (marked '*C*' in figure 2 and in background of figure 3), and believe this occurred at a similar time. This affected a natural hillslope above the A830 on the opposite side of Loch Eilt. Although debris did not reach the road, two landslips in relatively close proximity demonstrates that slopes in this area were particularly vulnerable to the effect of the climatic conditions prevailing at that time.

Landslip characteristics

42 The gradient of the natural slope in the area of the landslip ranges between 25° and 30° with several streams flowing down the hillside and passing under the track into Loch Eilt.

43 The landslip involved an estimated 500 m^3 to 600 m^3 of material, weighing over 1000 tonnes. The top of the landslip started at a natural hollow about 80 metres outside the railway boundary fence, and 46 metres above track level (figure 9). The slip followed the path of an existing gulley, enlarging it significantly down to the level of the underlying bedrock (figure 10).

Figure 9: Existing natural hollow at top of slip

[3] Data from https://www.wunderground.com.

[4] The railway at the accident location is approximately 50 metres above sea level.

Figure 10: Side view of upper part of slip on natural slope

44 As the leading edge of the sliding debris approached the railway, it destroyed part of the catch-fence which had been installed in 2017 to trap falling rocks. It then spread out as a debris plume, 40 metres long below the level of the railway (figures 11 and 12). The displaced material included several large boulders, and a significant volume of water.

Figure 11: View showing nature of debris on downhill side of railway

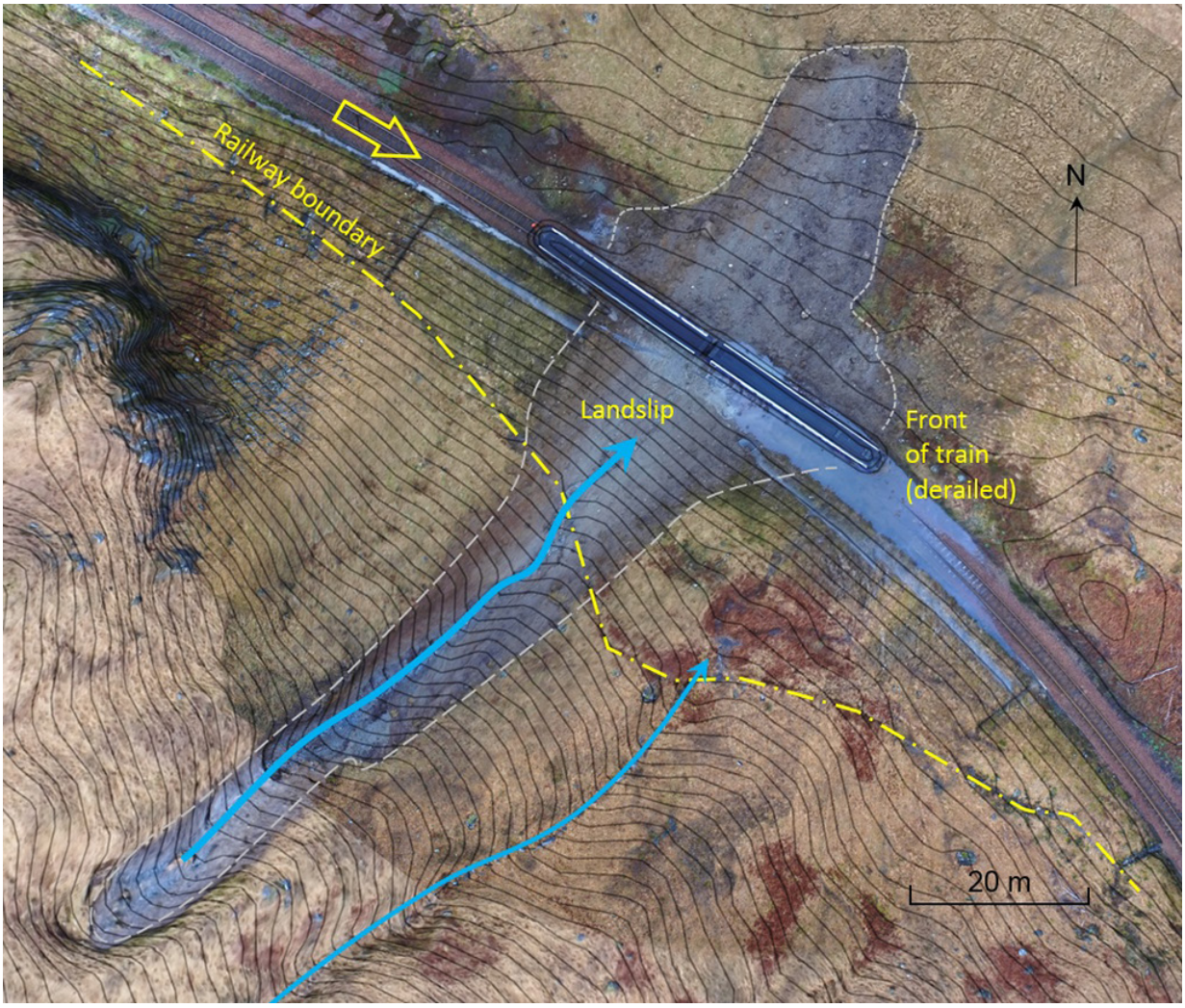

Figure 12: Landslip site showing railway boundary and post-accident contours at one metre intervals. The railway boundary on the uphill side is shown. Note: this 'orthomosaic' map is derived from multiple overlapping aerial photographs, and has been automatically adjusted for topographic relief, lens distortion, and camera tilt.

45 The British Geological Survey[5] defines a debris flow landslide as the rapid downslope flow of debris mixed with water. It states that:

> 'Debris flows are a widespread phenomenon in mountainous terrain and are distinct from other types of landslides as they can occur periodically on established paths, usually gullies and drainage channels. Debris flows in Great Britain are most commonly found in upland Scotland but also occur in parts of Wales and the Lake District. Debris flows are potentially very destructive and, due to the speed at which they take place, can for example rapidly block infrastructure routes.'

46 It is possible that the hollow in the ground at the top of the landslip (figure 9), a pre-existing feature, led to accumulation of snow and then melt water at a location which triggered a debris flow. Such topographical features are common on upland slopes and would not be considered a strong indicator of possible future landslips.

[5] The British Geological Survey is the national geological agency for Great Britain.

Identification of debris flow risk

47 Network Rail has a process in place to try to manage the risks posed by landslips on the railway, but the risk of a large debris flow landslip was not recognised at this location. Earthworks examiners applied slope risk management processes specified by Network Rail standard NR/L3/CIV/065[6], and used their professional judgement. Although the accident site is in an area where debris flows are known to occur, the actual location of these events is often unpredictable. In this instance, the earthworks examiners did not identify any features which would have indicated that this slope was at a higher risk of a large debris flow than other similar slopes adjacent to long lengths of railway elsewhere in the Scottish Highlands.

48 The last routine examination, in December 2017 resulted in the slope being described as being at 'average risk' of earthflow and washout (these are terms which overlap 'debris flow').

49 Earthworks examiners do not walk outside the railway boundary. However, they are expected to record information about hazards or significant risks from slopes outside the boundary by viewing them from within the boundary. This includes recording information about any loose boulders, evidence of landslips or significant drainage issues. The landslip area was only partly visible from inside the boundary but there is no evidence to suggest that the unseen areas contained features which differed significantly from those in nearby visible areas.

50 A detailed study[7] into several major landslides which affected the Scottish trunk road network in August 2004 found that debris flow landslides typically require relatively steep slopes. The minimum slope angle for debris flow activity is usually 30°, although it has been reported as low as 20°. The accident site slope angle was below 30° and did not suggest that this was a high risk location.

51 The study found that debris flows may occur when hillslope sediment cover (eg soil and loose rock) becomes rapidly saturated. The most important factor in debris flow occurrence is water. Heavy rainfall and/or snowmelt trigger the majority of flows, as the water mobilises the loose sediment.

52 The British Geological Survey landslides database contains over 17,000 reports. It has no records of previous major landslips around Loch Eilt.

53 Scotland Route maintained a list[8] of cuttings and embankments on Network Rail infrastructure which were assessed as being vulnerable to landslips during periods of severe rainfall. These slopes may be subject to additional monitoring as directed by the extreme weather action teleconference process (paragraph 37) during such periods. The list had never included the railway cutting slope between the railway and the natural slope on which the landslip originated.

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[6] Network Rail standard NR/L3/CIV/065 Examination of earthworks – issue 5, published December 2014.

[7] Scottish Road Network Landslides Study, Winter, Macgregor, Shackman, The Scottish Executive 2005.

[8] The list forms part of the 'Managing high risk earthworks during heavy rainfall' section of the 'Adverse and Extreme Weather plan' prepared by Network Rail Scotland.

Mitigation

54 In early 2015, Network Rail commissioned Fairhurst to undertake a geotechnical study of the slopes in the Loch Eilt area because they had been identified as requiring remedial action. The initial remit focussed on mitigation against risk from rockfalls and boulder incursions. Following a minor landslip in June 2015 (figure 13, and location '*B*' in figure 2), the remit was extended to include assessment of the risk from minor landslips originating outside the railway boundary. The 2015 event occurred about 150 metres west of the 2018 event, and deposited about 20 m^3 of material beside the railway. Like the 2018 event, the 2015 landslip also started outside the Network Rail boundary on a natural hillside, and followed an existing minor drainage channel down the natural hillside. A number of similar small streams flow down such channels and pass under the track into Loch Eilt.

Figure 13: view of minor landslip which occurred in June 2015 about 150 metres west of the 2018 accident landslip (photograph courtesy of Network Rail)

55 The areas selected for study had a combined length of about 3.25 km and included the site of the 2018 accident landslip. At locations where the study identified significant hazards, protection was provided in a £1.7M scheme completed in 2017. This included rock netting and catch fences of either standard or bespoke designs intended to prevent minor debris flows similar in size to that witnessed during the 2015 event from reaching the track.

56 At the site of the 2018 landslip, rocks were identified as protruding from the slope above the railway both inside and outside the railway boundary fence. To address the risk of rockfall due to these boulders becoming dislodged, a catch-fence was specified (figure 14). This catch-fence was intended to prevent boulders and other dislodged material, particularly that originating from within the Network Rail boundary, from reaching the track.

57 The catch-fence installed at the accident site was of a type used at other locations across Scotland route, and comprised a mesh fence supported by inclined wire ropes attached to ground anchors (figure 15). It was designed by Fairhurst, and was intended to be easy to install and maintain. The design was tested in a quarry in 2013, and found to be able to retain a 3 tonne boulder rolling down a slope 30 metres long with an angle of 35°.

Figure 14: Part of catch-fence installed in 2017 to trap falling rocks and boulders. The middle section was destroyed by the landslip. Part of the railway boundary fence is also visible in the foreground.

Figure 15: Detailed view of catch-fence supported by anchored cables

58 Following completion of the slope protection works, nearby slopes which had previously been included on the list of vulnerable slopes (paragraph 53), and were now protected, were removed from the list. This did not affect the accident location as it had not been included on the list.

59 **Network Rail was not aware of the landslip before train 1Y42 arrived at it.**

60 The previous train had passed almost seven hours earlier (paragraph 22), and Network Rail had no means of knowing that a landslip had occurred.

61 The absence of factors indicating a risk of a large debris flow (paragraph 47) meant that Network Rail did not install an automated landslip detection system as found at some higher risk sites on its infrastructure. However, Network Rail is considering more widespread implementation of enhanced landslip monitoring systems in future as technological advances make it practicable (refer to paragraph 77).

Factors affecting the severity of the consequence

62 **Action to control the leakage of diesel fuel from the train was delayed.**

63 Mitie was employed by Network Rail to provide pollution control services for an area covering most of the western side of the UK. Under the terms of the contract, Mitie was required to provide rapid response for decontamination services following a chemical, oil or fuel spill. It was required to provide a 24 hour service and to attend site within two hours of receiving an emergency call out. This was in order to take action to contain the spill and minimise migration of the spill from Network Rail infrastructure to sensitive areas including fisheries downstream of the loch. Mitie was required to ensure that all staff needed to work on or near the railway track held a current personal track safety (PTS) certificate.

64 Network Rail notified Mitie of the pollution incident at 10:16 hrs on Monday 22 January, and Mitie has confirmed that it treated the request as an emergency call out. Due to the remote location and nature of the incident, it instructed a specialist sub-contractor, located in Scotland with the capability to deal with oil spills, to attend. Network Rail had previously approved Mitie's use of this sub-contractor as part of Mitie's response arrangements.

65 At 12:16 hrs, a representative from the sub-contractor contacted Network Rail stating that, as the resources were to be deployed from Glasgow, its estimated time of arrival at site would not be until 17:00 hrs. As this would be after dark, the sub-contractor was asked to report to site at 08:30 hrs the following day. It was also told that Network Rail staff were still assessing the stability of the area following the landslip.

66 On Tuesday 23 January, staff from Mitie's sub-contractor arrived at the designated railway access point adjacent to the A830 road at Arieniskill (figure 2). They were instructed to wait nearby until rail transport to the site was available. At 11:15 hrs, Network Rail transferred control of the sub-contractor from Mitie to a different contractor who was managing the accident site on its behalf. The sub-contractor's staff who attended did not have PTS certificates and alternative arrangements had to be made to allow their entry onto the railway. Also, access to the accident site from Arieniskill required all personnel to await their turn to use a single rail-mounted personnel carrier. The sub-contractor's staff did not reach the train until 15:00 hrs, almost 29 hours after Mitie received the emergency call out.

67 The sub-contractor's staff identified that some diesel fuel had already entered the loch and deployed a floating pollution control boom to minimise further spread before leaving site on 23 January. They identified that escaped diesel was migrating towards the loch through track drainage channels running parallel to the railway before discharging into a burn flowing into the loch and by seeping through and over marshy ground below the railway. Over the following three days, they took steps to control the spread of diesel fuel by placing further floating pollution control booms in the loch and absorbent materials at other locations including around the train and along the track drainage.

68 The Scottish Environment Protection Agency (SEPA) has informed the RAIB that despite the delayed start, it was generally satisfied with the overall response to the pollution incident.

Observation

69 **Snowmelt and ground thaw risk was not appreciated.**

70 Network Rail's extreme weather process did not consider the additional landslip risk created by snowmelt and thawing of already saturated ground. These factors would have had the effect of increasing the amount of water available to cause landslips, but the risk was not recognised because the process for interpreting the forecast was insufficient. The sudden increase in temperature from below to above freezing was forecast without reaching the 13°C threshold used to trigger a yellow 'be aware' warning of a large temperature change.

71 It is unlikely that the Loch Eilt accident would have been avoided even if a warning of rapid snowmelt and ground thawing had been received unless the slope or fence was monitored (refer to paragraph 77). This is because the accident location was not on Network Rail's list of locations vulnerable to landslips during periods of high rainfall. It was therefore unlikely that Network Rail would have included it in any list of sites considered vulnerable to landslips triggered by water from snowmelt and ground thawing. The accident would only otherwise have been avoided if a snowmelt/ground thaw warning led to implementation of severe restrictions to train services over the large area which would have been covered by a warning of this type.

Summary of conclusions

Immediate cause

72 Train 1Y42 collided with a landslip while travelling at a speed of around 40 mph (64 km/h) (paragraph 31).

Causal factors

73 The causal factors were:

- Landslip debris obstructed the line as a result of weather conditions that combined to increase the risk of slope instability (paragraph 34); and
- Network Rail was not aware of the landslip before train 1Y42 arrived at it (paragraph 59).

Factor affecting the severity of consequences

74 Action to control the leakage of diesel fuel from the train was delayed (paragraph 62, **Learning point 1**).

Observation

75 Snowmelt and ground thaw risk was not appreciated because the process for interpreting the forecast was insufficient (paragraph 69, **Recommendation 1**).

Previous RAIB recommendations

76 The RAIB has investigated several individual accidents due to landslips and published two class investigations relating to landslips[9] and management of earthworks[10]. The associated recommendations cover a range of earthworks issues, but none are directly relevant to the factors identified at Loch Eilt:

- effective examination process;
- effective management of earthworks;
- effective drainage;
- responses to adverse weather; and
- management of landslip and drainage risk from neighbouring land.

[9] Class investigation into landslips affecting Network Rail infrastructure between June 2012 and February 2013, RAIB report 08/2014.

[10] Network Rail's Management of Existing Earthworks, RAIB report 25/2008.

Actions reported as already taken or in progress relevant to this report

Action reported that addresses a factor which otherwise would have resulted in a RAIB recommendation

77 Network Rail has an ongoing process to expand its existing programme of monitoring slopes with known or suspected instability issues. This includes on-going consideration of technological advances. Recent developments include a pilot study beginning in mid-2018 to monitor 200 higher risk cuttings nationally. Some systems being tested involve alarms being triggered based on measurements taken by arrays of closely-spaced tilt meters (ground movement detectors). Although not classified as a higher risk location, monitoring equipment was installed at the incident site prior to the line re-opening to warn of a similar event at the same location.

Other reported actions

78 Scotland Route has requested that Network Rail's weather forecasting service includes snowmelt risk as part of the written forecast produced each day. The organisation which produces the forecasts is not currently able to give a site-by-site numerical value for water released through snowmelt that can be used as an operational tool.

79 Network Rail is currently developing the specification for weather forecasts to be provided from 2020 onwards. Although snow accumulation, and thus thawing, is difficult to model the RAIB notes that updating this specification provides an opportunity to consider an enhanced snowmelt and ground thaw forecast, allowing improved management of landslip risk during these conditions (Recommendation 1).

Recommendation and learning point

Recommendation

80 The following recommendation is made[11]:

1 *The intent of this recommendation is to promote development of methods to evaluate the risk presented by snowmelt and ground thaw*.

Network Rail should complete its evaluation of the means by which snowmelt can be incorporated in adverse weather processes applicable to earthworks. It should also carry out a similar evaluation for risk due to ground thaw.

If justified by these evaluations, Network Rail should include improvements in monitoring these effects for the next generation of its weather information tools, such that the true level of risk associated with such a combination of weather conditions is accounted for in its management of landslip risk (paragraphs 75 and 79).

Learning point

81 The RAIB has identified the following key learning point[12]:

1 The accident demonstrates the importance of having effective and verified arrangements in place for call-off contracts, particularly those covering the response to environmental hazards in remote and inaccessible areas. This should include suitable arrangements to allow staff prompt and safe access to the track (paragraph 74).

[11] Those identified in the recommendation have a general and ongoing obligation to comply with health and safety legislation, and need to take this recommendation into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, this recommendation is addressed to the Office of Rail and Road to enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

[12] Learning points' are intended to disseminate safety learning that is not covered by a recommendation. They are included in a report when the RAIB wishes to reinforce the importance of compliance with existing safety arrangements (where the RAIB has not identified management issues that justify a recommendation) and the consequences of failing to do so. They also record good practice and actions already taken by industry bodies that may have a wider application.

Appendices

Appendix A - Sources of evidence

The RAIB used the following sources of evidence in this investigation:

- Information provided by witnesses;
- Information taken from the train's on-train data recorder;
- Closed circuit television (CCTV) recordings taken from train 1Y42;
- Site photographs and measurements;
- Weather reports and observations at the site;
- Earthworks examination records;
- Catch-fence design documents;
- BGS landslip records;
- Scottish Road Network Landslides Study 2005; and
- A review of previous RAIB investigations that had relevance to this accident.

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