Rail Accident Investigation Branch

Rail Accident Report

Derailment at Oubeck North near Lancaster
4 November 2005

Department for Transport

Report 19/2006
November 2006

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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Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given to Network Rail, TransPennine Express, Alstom and Angel Trains Ltd staff, data and records for the purpose of this investigation.

4 Appendices at the rear of this report contain Glossaries explaining the following:

- acronyms and abbreviations are explained in the Glossary at Appendix A; and
- certain technical terms (shown in *italics* within the body of this report) are explained in the Glossary at Appendix B.

Summary of the report

5 On the afternoon of 4 November 2005, passenger train 1C62, a three car Class 175 *Diesel Multiple Unit* (DMU) operated by TransPennine Express, travelling on the *down line* of the Preston to Lancaster section of the West Coast Main Line, derailed after running into a *landslip* in a *cutting* at Oubeck North. The location is shown in Figure 1.

Figure 1: Extract from Ordnance Survey map showing location of incident

6 The *trailing wheelset* on the leading bogie derailed to the *six foot*. No other wheels were derailed. The train travelled a further 1430 m before coming to rest in an upright position.

7 There was no collision with structures or other trains and there were no injuries as a result of this derailment.

8 Two *coupler lateral bump stops* were dislodged from the leading vehicle and came to rest 200 m after the landslip. They caused damage to the *underframe*, including holing the fuel tank on the leading vehicle.

9 There was extensive damage to the *rail fastenings* over the length of track that the train ran on in a derailed state. Additionally, eighteen rail fractures to the six foot rail were identified (nine complete failures, seven with loss of rail section at the rail foot and two partial cracks).

10 As a result of this consequential damage, both the *up line* and the down line were blocked until shortly after 03:00 hrs on 7 November.

11 The immediate cause of the derailment was the train running into material deposited on the track as a result of the cutting landslip.

12 The cutting slope failed due to the volume of water flowing through a field drain into the body of the cutting slope. The volume of water flowing through the field drain was likely to have been greater than usual due to the wet period over the preceding two weeks and excessive rainfall during the previous day. The root cause was that the field drain was hidden from view.

13 The following factors contributed to the failure of the cutting slope:

- the degree of reliance placed on standards other than Network Rail's *earthwork*s examination standard (NR/SP/CIV/065) in managing the overall risk associated with cuttings, and the associated reporting arrangements;
- the practicality of executing all of the inspections specified in Network Rail's earthworks examination standard (NR/SP/CIV/065), particularly considering the inaccessibility of the cutting slope, and not including such limitations when assigning the risk to the cutting;
- the lack of guidance on the *evaluation* process; and
- the classification of the cutting as *serviceable* (low risk).

14 The immediate cause of the detachment from the train of the coupler lateral bump stops was the slotted design of the mounting arrangement combined with a set of forces generated by collision with the landslip and the absence of secondary retention.

15 The root cause is that the design process did not anticipate a longitudinal element of a load combination similar to that experienced at the coupler head during this accident scenario in combination with the other loads.

16 The immediate cause of the rail fractures was the impacting of the *raised collars* of the *Thermit* welds by the derailed wheel *flange tip*.

17 Six recommendations are made in the following areas, to improve safety (paragraph 170):

- modifications to be made to intercept the field drain on Network Rail property and discharge via an engineered drain;
- identification, prioritisation and management of cutting slopes significantly prone to *earthflow* failure due to drainage flows from neighbouring property;
- changes to the standards associated with overall earthwork and drainage examination regime;
- industry review of design base *load case*s experienced at the coupler;
- review of the design of the coupler lateral bump stop mounting arrangements;
- implementation of any design modifications on the Class 175 and 180 trains.

The Investigation

Summary of the incident

18 At approximately 13:56 hrs on Friday 4 November 2005 passenger train 1C62, the 12.35 hrs Manchester Airport to Windermere, was travelling towards Lancaster on the down main line of the West Coast Main Line, when it ran into a landslip in a 6 m high cutting at Oubeck North (18 miles 320 yds) and derailed.

19 As a result of the derailment two coupler lateral bump stops were dislodged from the train and 18 fractures were caused to the six foot rail.

Background

Investigation process

20 The cause of the landslip was determined by investigation of:

- infrastructure condition;
- the inspection regime, including prior knowledge;
- the weather; and
- the slip mechanism.

21 The derailment mechanism and consequential damage to the train were assessed by consideration of the:

- train design and industry standards;
- consequential damage to the train; and
- size and content of the landslip.

22 The cause of the infrastructure damage was determined by inspection of the track.

23 Network Rail's Territory Track Engineer (London North Western Territory) produced an investigation report [TTE-LNW-31.1.Oubeck (04/11/05)] against a remit defined by the RAIB, which drew on evidence presented to the Network Rail Formal Investigation. Information presented in the Network Rail report forms part of the basis for this report. Additional evidence from the *Territory Earthworks and Drainage Engineer* has been considered in the investigation.

The infrastructure

24 The railway infrastructure is owned and maintained by Network Rail. At the time of the incident the cutting bank was examined, as part of the maintenance regime, by Babtie, a firm of consultants, on behalf of Network Rail. Any work required would be undertaken by Network Rail. The land bordering the railway at the site of the landslip is owned by a private third party.

25 The incident occurred in the cutting just north of Oubeck (17 miles 1694 yds) at 18 miles 320 yds. Oubeck is located approximately 3 km south of Lancaster adjacent to the A6 road (see Figure 1).

26 The track at the point of derailment has a permanent speed restriction (PSR) of 110 mph (176 km/h), and a curve of 2504 m radius to the left in the direction of travel. The gradient rises at 1 in 410 in the direction of travel and there is an installed *cant* of 70 mm.

27 The cutting slope on the west side is approximately 6 m high, with a 30° inclination (see Figure 2). It is uniformly covered in low but dense scrub and bramble vegetation. The body of the slope is made of brown sandy clay and *glacial till* covered by a top soil and vegetation layer held together by roots.

28 At the top of the cutting there is a 5 m wide margin of almost level ground, bordered by a post and seven strand wire fence which demarks the Network Rail boundary to the adjoining grassed pasture land.

29 There is a *cess drain*, but no *crest drain* or surface drainage on the cutting. At this location and to the south of the failure site the cess drain is a piped system, containing several chambers at approximately 50 m intervals.

30 There is a *signalling and telecommunication* (S&T) trough route supported on stub concrete posts at 1.5 m centres set into the *slope toe*.

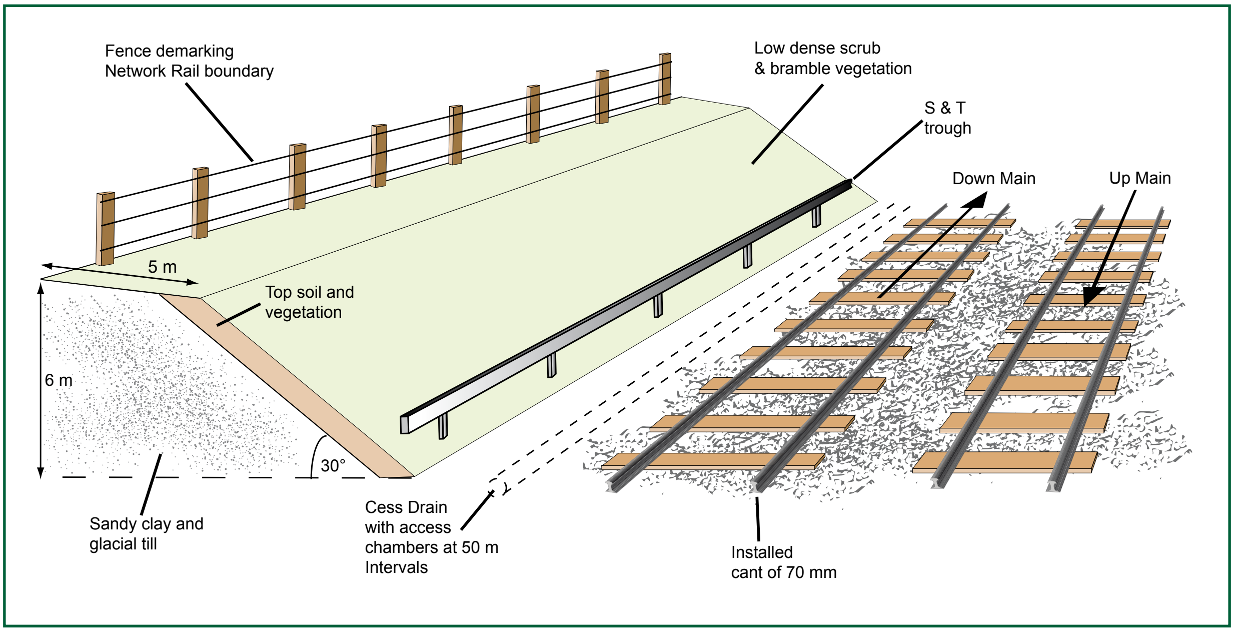

Figure 2: Diagrammatic presentation of the cutting slope prior to failure

<u>The train</u>

31 Passenger train 1C62 was a three car Class 175 DMU (unit number 175103).

32 The train was designed, built and maintained by Alstom, entering service in 2000. It is owned by Angel Trains Ltd and operated by TransPennine Express. Arriva Trains Wales operates these trains on the Cardiff to Holyhead route.

Events preceding the incident

33 On Friday 4 November 2005 passenger train 1C62, the 12:35 hrs Manchester Airport to Windermere, was travelling towards Lancaster on the down main line of the West Coast Main Line.

34 The train was travelling at approximately 92 mph (147 km/h) and carrying 141 passengers.

Events during the incident

35 At approximately 13:56 hrs the train ran into a landslip at Oubeck North. The trailing wheelset on the leading bogie on the leading car derailed to the six foot. No other wheels were derailed. The train came to rest in an upright position after travelling a further 1430 m.

36 There were no injuries, although one passenger was airlifted to hospital with a suspected angina attack.

37 There was no collision with structures or other trains. A freight train on the up main line was stopped by emergency hand signals given by the driver of train 1C62. This prompt action by the driver prevented the consequences being more serious.

38 Two coupler lateral bump stops were dislodged from the leading vehicle and came to rest 200 m after the landslip. They caused damage to the underframe including holing the fuel tank on the leading vehicle as shown in Figure 3.

Figure 3: Hole in fuel tank

39 The derailed wheelset caused extensive damage to the rail fastenings, *sleeper*s and rails over a distance of 1430 m. Additionally, eighteen rail fractures of the six foot rail were identified, comprising nine complete failures, seven with loss of rail section at the rail foot and two partial cracks. Examples of the three different types of fractures are shown in Figure 4.

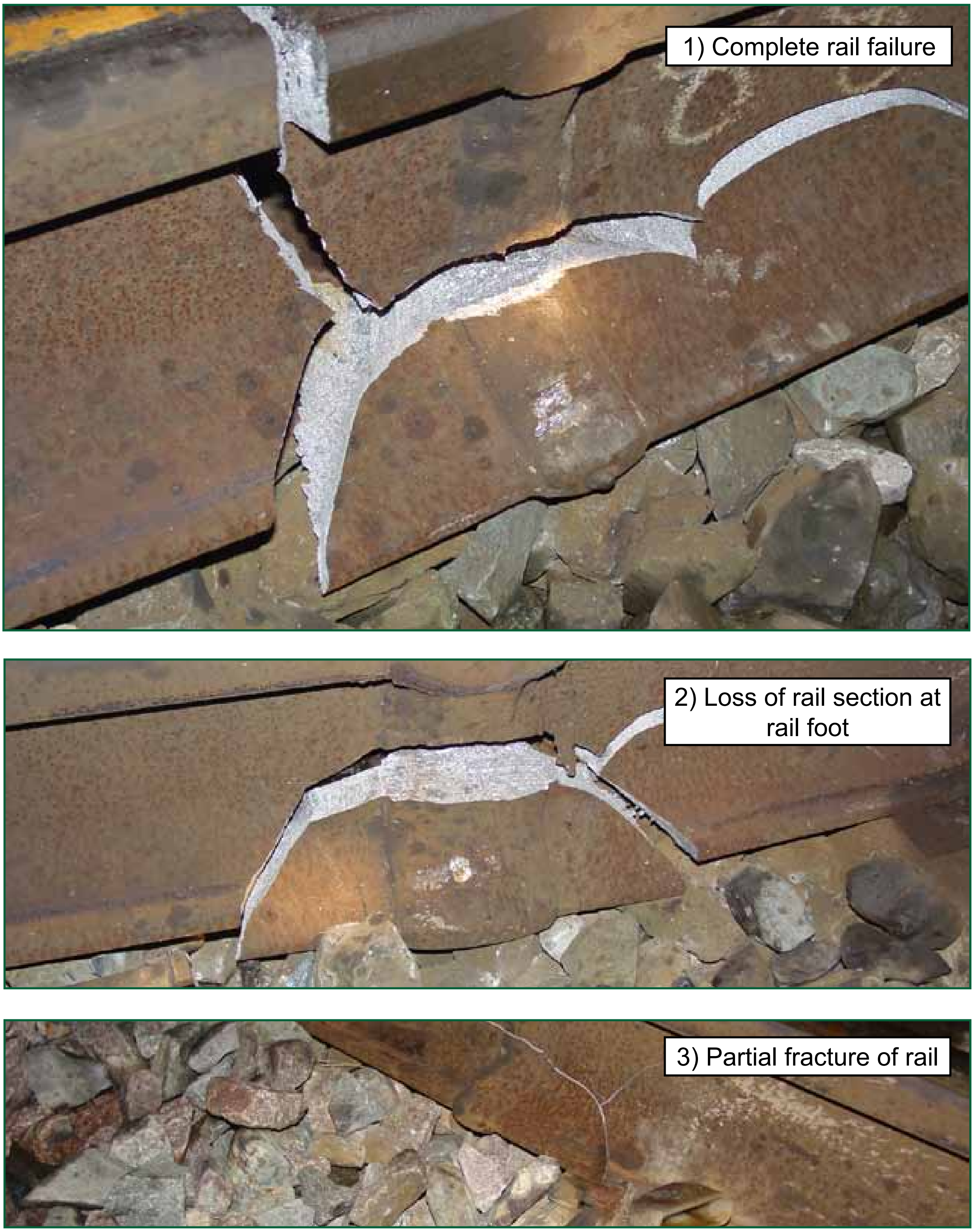

Figure 4: Examples of three different types of rail fractures observed

Key Evidence

40 The evidence investigated is presented in this section.

Maintenance and inspection records

41 *Track Recording Vehicle* (TRV) fortnightly, and more latterly weekly, records over the previous 12 months show no problems and consistent measurements indicating good *formation* stability.

42 Maintenance Records show that no maintenance was considered necessary by Network Rail or carried out in the 3 months preceding the incident, including infrastructure adjacent to the landslip.

43 West Coast Route Modernisation Programme records shows that the *ballast* and sleepers had been replaced, including those adjacent to the landslip, in January 2004, with the sleeper condition being the main driver for the replacement.

44 The Earthworks and Drainage Examination Report (CGJ6/2100/LH/018/03), undertaken on 24 April 2003 by Babtie on behalf of Network Rail, reports the findings from the last examination of the cutting at Oubeck North. It reports the slope as serviceable, which is the lowest level of risk, and allows for a period of 10 years before the next inspection. It does not identify any defects or specific actions to be taken; however, it reports the cutting slope to be 95 per cent inaccessible. It reports that the face was dry, that there was no drainage of adjacent land or visible crest drainage, and that the condition of the cess drain was unknown. It states a uniform *slope crest,* and records that the history of previous failures was unknown.

Network Rail's Infrastructure Standards

45 Network Rail's Standards NR/SP/CIV/065 (Examination of Earthwork) and NR/SP/TRK/001 (Inspection and Maintenance of *Permanent Way*) identify the inspections that are to be undertaken on earthworks and drainage.

46 NR/SP/CIV/065 is the primary standard, being specifically targeted at managing the risks associated with earthworks. Compliance to this standard was not mandated at the time of the examination of the slope, however the examination was undertaken based on a specification which subsequently formed the basis for NR/SP/CIV/065. Additionally, RT/CE/P/30, the predecessor to RT/CE/S/086 (Management of Existing Earthworks), relevant at the time of the inspection, references NR/SP/CIV/065 as being applicable.

47 Network Rail's standard NR/SP/TRK/001 places responsibilities on track inspectors to inspect track drainage and identify any signs of inadequate drainage on ballast condition. Additionally, it includes the following section:

'To the extent that it is reasonable to do so in the course of track inspections, the following items shall also be identified and reported:

Cutting and embankment slopes:

Signs of loose, displaced or fallen material (particularly after severe frost, heavy rainfall or thaw);

Signs of cracking (particularly in clay slopes during very wet weather);

Signs of movement where large trees are present that may fall onto the track.'

48 The output from examinations carried out in accordance with NR/SP/CIV/065 is twofold. Firstly the slope is assessed for *stability risk* by observing specified parameters and applying a score to each. The risk is classified, in reducing severity, as *poor*, *marginal* or serviceable, and is used to define the maximum period to the next examination. Secondly, defects and specific action to be taken are identified.

Post-incident site investigation

49 Post incident site investigations revealed that the landslip left a *scar face* approximately 10 m long and 2.5 m high on the cutting slope.

Figure 5: Landslip at Oubeck North looking in the direction of traffic

50 The length of the debris deposited on the track was about 10 m. It was between about 0.5 m and 1 m high at the cess rail falling sharply to a few centimetres on the six foot rail. The material on the track did not show any disturbance as a result of a train running through it. Figure 5 is a photograph of the landslip taken on the day following the incident looking in the direction of travel.

51 The landslip material comprised slabs of turf with saturated flow deposits behind. The material on the track was supersaturated and mainly consisted of soil and clay material, but also contained a number of large boulders, several of which were reported as being in excess of 500 mm in diameter. Figure 6 gives an indication of the consistency and shows a boulder of the order of 200 mm diameter in the landslip, indicated by the arrow. This photograph was taken during the digging out process on the day following the derailment.

52 During the remedial work three distinct streams were noticed flowing from the slope crest. Excavation of the slope exposed a 100 mm diameter historic earthenware field drain approximately 0.5 m below ground level issuing water onto the scar face at approximately 1 litre/s.

Figure 6: Indication of consistency and boulders in the landslip material

53 A depression in the grazing pasture land approximately 50 m beyond the railway fence line was noted as retaining between 50 and 100 mm of water. The texture and nature of the grass in the depression indicated that it would normally be free of standing water. No recent changes to use or vegetation in this area were noted.

54 During the remedial work the vegetation was cleared from the top of the cutting for a distance of approximately 25 m north and south of the landslip location. This revealed an obvious step in the slope crest. This may have been an indication that there had been a previous failure at this location. The step was very rounded and buried by deep vegetation. Additionally, a site of possible previous *toe heave* was identified.

55 The cess drain at this location and to the south of the failure site was a piped system, containing several chambers at approximately 50 m intervals. The cover of the nearest chamber to the derailment site was removed to reveal that the drain was free flowing. Each of the chambers contained inlet pipes of about 100 mm diameter coming from the direction of the slope. One of these chambers was roughly in line with the outflow from the field drain. It is uncertain whether the pipes in the chambers are connected to *carrier drain*s connecting the field drains to the cess drain. No records were made of any discovery of the remains of any pipes connecting the exposed field drain to the cess drain during the excavation and repair of the slope. The site findings are shown in Figure 7.

56 The general track, ballast and sleepers were in good condition. There were no visible rail head marks that could be attributed to the derailment. The first damaged rail fastener was on the six foot side on the 10th sleeper after the landslip material on the track. There were also marks on the sleepers, 2 sleepers after this, indicating that the cess wheel must have been derailed at or before this point.

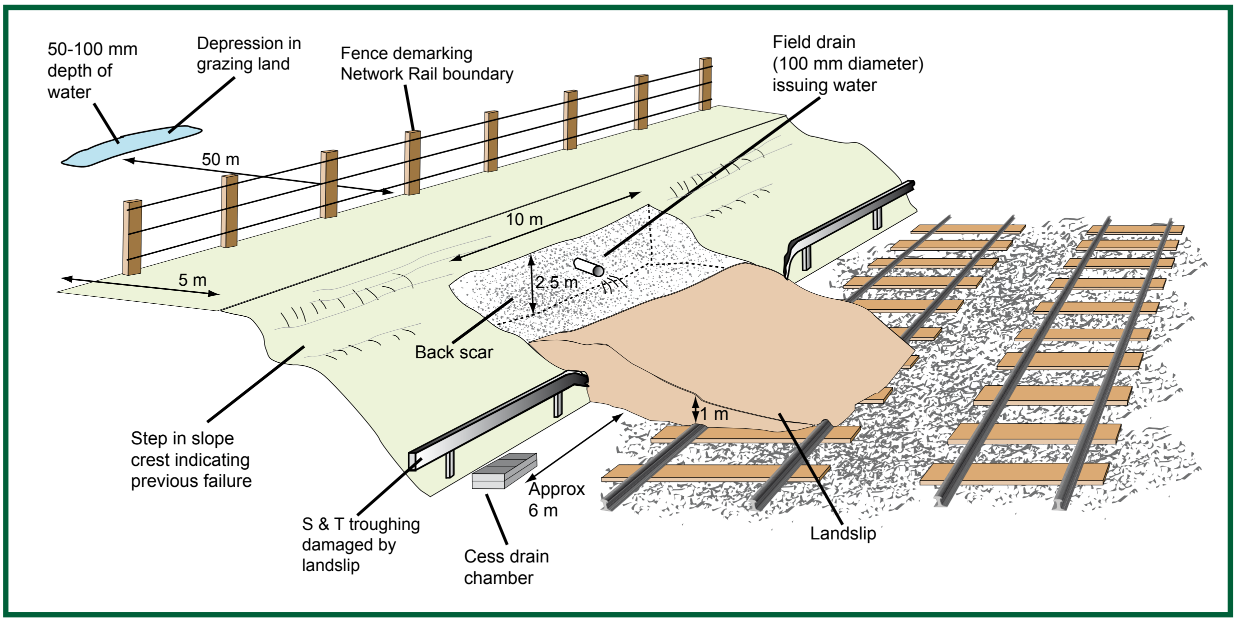

Figure 7: Cutting slope after landslip

57 There was extensive consequential damage to the rail fastenings over 1430 m, the distance the train ran derailed. Additionally, 18 new rail fractures to the six foot rail were identified, all at the raised collars of Thermit welds. Other Thermit welds on the same track were not fractured. No sections of rail head were broken away or detached.

58 On the day after the incident, two coupler lateral bump stops were found in the cess in the region of 18 miles 540 yds, approximately 200 m from the point of derailment. Additionally, a cab foot step was also found in the same area.

<u>Records and logs</u>

59 Rainfall data from Meteorological Station No: 7236 since 1976, allowed the amount of rainfall to be determined for the preceding day and two weeks, and historical averages to be calculated (see paragraphs 105 and 106). [1]

60 Network Rail Territory Control Centre Logs recorded that there were two floods and another landslip (at High Bentham) on the Railway within a 30 mile radius during the 14 hours preceding the accident.

61 There were no driver reports indicating any deterioration of the cutting at this location during the 24 hours preceding the accident. The *Rule Book* requires that drivers notify the signaller of anything that may put trains in danger.

62 Discussions with a person from the locality indicated that an historical failure had occurred at this location, but nothing recently. It has not been possible to corroborate this as there are no formal records.

63 The driver believed that prior to the collision the debris mound was approximately level at 1 m high, but slightly higher on the cess rail side.

64 The *Train Data Recorder* indicated that the train was travelling at 92 mph (147 km/h) when it first encountered the landslip.

[1] Weather data provided courtesy of Lancaster University

Train inspection

65 The train was examined at the site of the derailment prior to re-railing (see Figure 8), at Carnforth on 16 November 2005 and at Alstom Trainline Services, Wolverton on 30 November 2005 (before cleaning) and 9 December 2005 (after cleaning). The key findings are summarised in the following paragraphs (left and right hand sides are relative to the direction of travel when the train hit the landslip).

Figure 8: Exterior of the vehicle following derailment

66 The coupler lateral bump stops were missing from the train. These are normally located in the *coupler pocket*. This area was extensively coated in mud consistent with the landslip debris, as were the surfaces of the mounting brackets for the coupler lateral bump stops. Copper pipework located behind the brackets was severely damaged.

67 The left hand *air suspension surge reservoir* was adrift and punctured. There were paint marks adjacent to the hole. The shape of the puncture and adjacent paint marks matched the shape of the coupler lateral bump stops and the *tell-tale* paint marks on their bolts. The right hand surge reservoir mounting was bent, and the reservoir dented.

68 The *Track Circuit Actuator* (TCA) bracket was torn in two places (matching damage marks on one of the coupler lateral bump stops) and the TCA antenna loop itself was bent up at the rear of the loop along the centre line of the vehicle.

69 The fuel tank on the leading vehicle was impacted and holed. The shape of the hole is compatible with the corner of a coupler lateral bump stop.

70 The front projected surfaces on the left hand axle boxes on the leading bogie exhibited significant mud and debris deposits.

71 Other areas of the train that incurred damage included:

- cab Glass Reinforced Plastic (GRP), left hand side foot step and windscreen;
- *coupler electrical head*, including loss of its cover plate;
- *Automatic Warning System* (AWS) bracket; and
- the final drives on the leading axle of the trailing bogie on the leading vehicle and on the leading axle of the middle vehicle exhibited signs of heavy impact.

72 There was no sign of any structural deformation indicating collapse of the cab *crashworthiness* structure and the tell-tale in the *coupler shank* was still in place, indicating that there had been no permanent axial compression.

Industry standards for trains

73 The primary standards against which rail vehicles need to be designed and demonstrated compliant are the *Railway Group Standards* produced, on behalf of the rail industry, by the Rail Safety and Standards Board (RSSB).

74 The current issue (Issue 3) of GMRT/2100, Structural Requirements for Railway Vehicles, states in Clause 10.1:

‘Equipment and components mounted directly or indirectly to a vehicle body shall remain attached during normal operation and, as far as practicable, remain attached in the event of derailments, heavy shunts and minor to medium collisions.’

75 Issue 3 of GM/RT2100 is dated October 2000. Issue 2 (April 1997), the version against which the Class 175 was designed, does not include the above statement, but states that equipment attached to vehicle bodies is required to meet the requirements of GM/TT0179, Structural Requirements for Body-mounted Equipment on Railway Vehicles, which includes the following two requirements:

‘Equipment and mountings shall resist without failure all forces likely to be encountered both under normal conditions such as heavy shunts and minor to medium collisions. If failure does occur as a result of a collision or derailment the possibility of injury to people shall be minimised, both inside and outside the vehicle.’

‘Equipment and mountings shall be designed to take into account the risks and consequences of failure. Where appropriate, risks shall be reduced by measures such as overdesign of mountings and attachments, the use of fasteners incorporating high strain energy, the provision of emergency restraints, and the installation of failure detection and warning devices.’

76 Her Majesty’s Railway Inspectorate’s *Railway Safety Principles and Guidance* Part 2 Section F, Guidance on Trains (dated 1996) includes the following two clauses:

Clause 134: ‘Items of equipment, their ancillary mountings, fittings etc, both inside and outside the train, should be suitably secured. They should be designed to withstand the range of loads that they may experience throughout their life, including vibration, thermal loading, extreme operational loading, accident loading, foreseeable abuse and vandalism.’

Clause 135: ‘Consideration should be given to the effects of equipment attachment failure which could adversely affect the safe operation of the train or of passengers within it or of people adjacent to the lineside or on station platforms. Redundancy in attachment or secondary security may be appropriate.’

Coupler lateral bump stop design information

77 The coupler lateral bump stops are bolted onto plates mounted onto the *cab structure*, as shown in Figure 9. The lower edge of the coupler lateral bump stops is 787.5 mm above rail height.

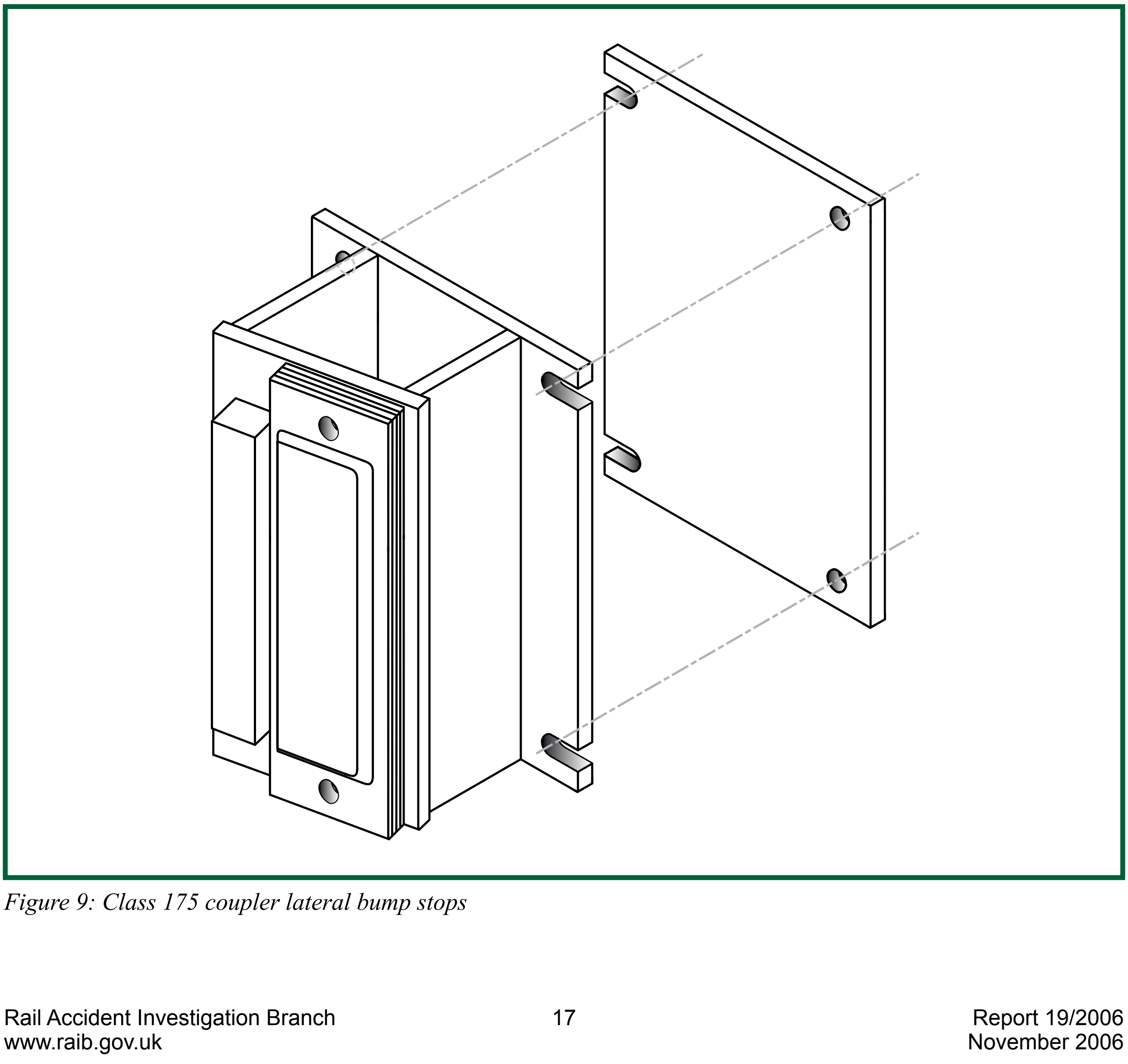

Figure 9: Class 175 coupler lateral bump stops

78 The holes are slotted on the leading edge of the coupler lateral bump stop plate and on the trailing edge of the headstock, all other holes are drilled. Alstom, the train manufacturer, has advised that this arrangement is to ensure that the coupler lateral bump stops do not prevent the coupler retracting in a significant collision, thereby avoiding 'bridging out' the crashworthiness performance of the train structure.

79 Alstom reported no evidence of previous problems with the coupler lateral bump stops becoming loose or being dislodged.

80 Alstom reported that the design of the coupler lateral bump mounting arrangement was not subjected to detailed calculation or test during design approval or commissioning. However, following the accident the mounting arrangement has been assessed against a longitudinal acceleration of 5 g (49 m/s^2), the proof load case, and a separate lateral load of 100 kN, quoted as being the 'jack-knife' load case, from GM/RT2100 (table 2, load case w). The same requirements appear in both Issues 2 and 3). Additionally, the energy that a projectile impacting the coupler lateral bump stop would require to dislodge it has been calculated. The Alstom analysis (D01/CAL/066 Issue 1 12/12/05) shows that the coupler lateral bump stop mounting arrangement meets the Railway Group Standards with respect to the load cases selected and that between 0.5 and 1 kJ of energy is required to dislodge a coupler lateral bump stop. The latter is equivalent to hitting a 1.25 kg stone at 100 mph (160 km/h), which is the maximum speed of the Class 175 trains.

Analysis

<u>Infrastructure condition</u>

81 The evidence from the TRV records and the post incident site investigations indicate that neither track geometry nor track components contributed to the cause of the derailment.

82 No maintenance had been considered necessary or carried out on the track, drain, structures, earthworks or fencing in the preceding three months and therefore the landslip was not initiated by recent changes to the infrastructure.

83 The post-incident inspection of the cess drain revealed that it was free flowing, and therefore functioning.

84 During the remedial activities on the cutting a field drain was discovered discharging water from nearby pasture land into the cutting slope. It has not been possible to confirm whether this drain was designed to discharge into the body of the cutting or to connect to a carrier drain down to the cess drain.

85 There may have been a previous failure of the cutting slope at this location, evident by the step at the slope crest, corroborated by comments made by a local person (see paragraph 62). The vegetation coverage of the slope was such that the evidence of the previous failure was not visible from the track or slope crest. Additionally, there was evidence of a site of possible toe heave. There was however no evidence (eg *survey targets*) of specific monitoring at the site prior to this incident.

86 No other aspect of the infrastructure had any bearing on the derailment.

<u>Inspection régime</u>

87 Network Rail's earthwork examination process has been improving over recent years with the introduction of a specific company standard (NR/SP/CIV/065). This requires periodic collection of information and examination of cuttings.

88 Examinations undertaken in accordance with NR/SP/CIV/065 are the only examinations specifically targeted at assessing the condition of the cutting slope and related drainage. Track drainage inspection is covered by NR/SP/TRK/001.

89 The periodicities of earthwork and drainage inspections vary between 1 and 10 years. Network Rail relies on the vigilance of permanent way staff during their weekly track inspections to identify any cutting degradation in the period between the specific earthwork examinations. However, there is no evidence that track inspectors receive formal training or need to demonstrate competence in identifying earthworks failures, or their associated warning signs. Some areas of Network Rail have adopted informal aide memoirs to assist their staff in this task.

90 NR/SP/TRK/001 does not require that the Territory Earthworks and Drainage Engineer is informed of relevant findings or that it was 'not reasonable' (see paragraph 47) for the permanent way staff to make the observations requested.

91 NR/SP/TRK/001 does not require any inspections of drains, other than those serving the track.

92 Permanent way staff focussing on formation, sleepers and track are unlikely to notice anything other than significant cutting failures under the present regime.

93 The earthworks examination regime does not clearly identify all of the specific examinations to be carried out by different groups of workers, the associated periodicities, and the arrangements for formal reporting. This is considered to be a contributing factor to the landslip.

94 NR/SP/CIV/065 states that the Earthworks Examiner shall physically walk over the surface of the cutting slope by means of traverses between the slope toe and crest at a minimum of one *chain* intervals. Allowance is made for the use of aerial photography where access is difficult.

95 The report from the Oubeck examination on 24 April 2003 states the slope to be 95 per cent inaccessible, although the examiner did collect much of the required information and made a characterisation of the condition of the bank. There is no evidence of any alternative arrangements being adopted to compensate for the lack of accessibility. The report has been signed off by the Earthworks Examining Engineer, it is therefore inferred that the examination was considered acceptable.

96 The standard specifically states that examination should identify blocked or broken drains. This cannot be achieved where the presence of drains is unknown.

97 The report from the Oubeck examination (24 April 2003) states that the condition of the cess drain was unknown. It is not clear whether this was because access to the cess drain was difficult. Had there been an inspection of the chambers then the input pipe may have been identified.

98 The examination did not identify indications of possible previous cutting failures (slippage and toe heave), both of which may have been identifiable if the bank had been subject to vegetation clearance and walked over.

99 Elements of the examination are not practical at all locations due to physical limitations and lack of knowledge of the physical asset, eg hidden drainage. Actions required to identify precursors to cutting failures should be clearly described in the governing procedure. Arrangements need to be made to facilitate the complete and correct implementation of the inspections. The impracticality of implementing the earthworks standard is considered to have been a contributing factor to the landslip.

100 The difficulty in executing some of the examination tasks was not identified as a risk in its own right. Both the findings and the limitations of any inspection should be considered when assigning the risk of a cutting. That this was not done is also a contributing factor to the landslip.

101 Network Rail requires that each earthworks examination report is subject to an evaluation by an Earthworks Examining Engineer. The Earthworks Examining Engineer checks for completeness and consistency with previous reports. Poor sites are identified and a list of them forwarded to the Earthworks Manager who determines which require a more detailed *assessment*.

102 The examination process is the subject of significant guidance, in NR/SP/CIV/065, however, there is no guidance on the evaluation and assessment processes. While this is considered reasonable for the assessment process, the lack of guidance on the evaluation process is considered a contributing factor to the landslip.

103 Since the poor earthworks are considered to be of greatest risk, the evaluation process tends to focus on these. This means that there is currently no formal process for confirming that the marginal and serviceable earthworks have been correctly classified. This is also considered a contributing factor to the landslip.

104 As no driver reported any deterioration of the cutting at Oubeck North during the 24 hours preceding the incident, it is likely that the development of the landslip was rapid. The trains that passed the landslip location immediately prior to the incident train, 1C65, were train 6P28 at 13:10 hrs on the down line and train 1M15 at 13:37 hrs on the up line.

The weather

105 The rainfall in the vicinity of the landslip over the two weeks preceding the incident was 134.6 mm. The average for this two week period since 1976 is 62.3 mm. The rainfall prior to the incident was twice the 30 year average. This value has only been exceeded during nine periods since 1976.

106 The rainfall during the preceding day was 45.4 mm. This level of rainfall has only been exceeded on seven days since 1976.

107 The occurrence of two floods and another landslip on the railway within a 30 mile radius of Oubeck provides further evidence of the severity of the rainfall in the area.

108 A depression in the grazing pasture approximately 50 m beyond the railway fence line was noted as retaining between 50 and 100 mm of rainwater. The texture and nature of the grass in the depression indicated that it would normally be free of standing water.

109 The significant rainfall over the period preceding the incident is likely to have saturated the surrounding ground and the excessive rainfall during the preceding day would have generated a large volume of runoff over land and through drains. The wet weather was a causal factor of the landslip.

The slip mechanism

110 A field drain at the top of the cutting was taking water from the adjacent land and feeding it onto Network Rail's land. It is common for field drains to be connected to carrier drains taking the collected water to the cess or alternative engineered drain. That this may have been the case at Oubeck is supported by the evidence of a pipe entering the chamber in the cess drain at the bottom of the slope, but no additional pipe work was found during the cutting repair work.

111 The field drain was hidden from view. This is considered to be the root cause of the landslip.

112 The bank consists of a glacial till (sand, gravel, silt, etc) underlying a layer of topsoil and vegetation.

113 Whether as a result of failure in a carrier drain from the field drain, or because the field drain was installed without an outfall, water was flowing into the body of the slope, locally elevating groundwater levels that were already high as a result of the prolonged wet period.

114 The heavy rainfall immediately prior to the incident saturated the topsoil and vegetation layer on the cutting slope surface. The resulting weight increase caused the upper 300 to 500 mm soil layer to slide down the bank (a *translational failure*).

115 The loss of the constraint on the underlying glacial till allowed it to flow. The liquefied soils flowed down to the south covering both rails and pushed the top soil to the north and further onto the track.

116 This earthwork failure is described as earthflow and is shown diagrammatically in Figure 10.

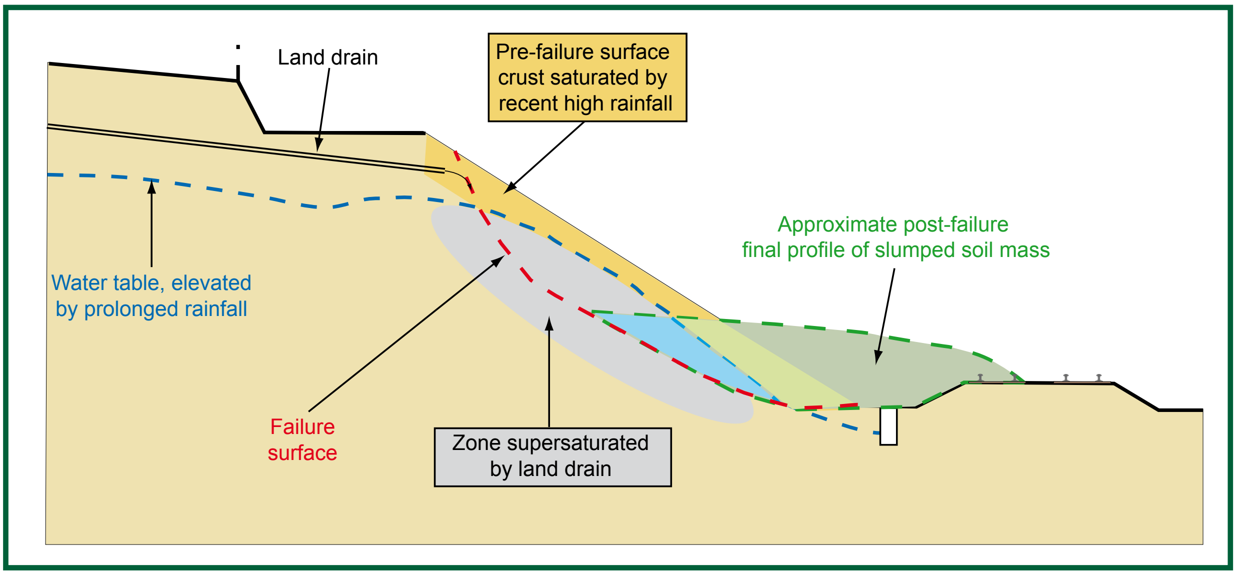

Figure 10: Sketch section through the failed cutting slope

Slip size and content

117 It is not possible to determine with any precision the dimension of the debris deposited on the track when the train ran through it, since the landslip continued to slide after the passage of the train.

118 The driver reported that the debris mound on the track was approximately level at 1 m high. However, inspection after the incident found it to be about 10 m long and 1 m high at the cess rail falling sharply to a few centimetres on the six foot rail. The damage to the train is consistent with the mound being significantly higher, or denser, on the cess side.

119 The material deposited onto the track had a thick liquid consistency with suspended denser matter. It was supersaturated and consisted mainly of soil and clay material with gravel and cobbles. It also contained a number of larger boulders.

120 The landslip damaged the S&T trough at the toe of the cutting. It is uncertain whether any debris from the trough reached as far as the track.

Derailment mechanism

121 No rail head marks could be identified and therefore the exact location of the point of derailment could not be established. However, the location of the first damaged rail fastener indicated that the wheelset must have derailed before it reached a point approximately 7.5 m (0.5 s) after hitting the landslip.

122 Only the trailing wheelset on the leading bogie derailed (to the right hand side). This required a set of force inputs sufficient to unload the right hand trailing wheel at the same time as a lateral force in the direction of the six foot. Three mechanisms have been identified that could have led to this:

- Asymmetric loading comprising a combination of longitudinal and lateral forces due to drag and impact applied to the *coupler head*, *obstacle deflector*, cab structure and leading axle box.
- A combination of vertical and lateral wheel force inputs due to running over debris encountered on the rail head.
- A vertical force input to the bogie frame due to running over debris encountered in the *four foot*.

123 It is not possible to conclude, with any certainty, which mechanism caused the derailment. Indeed, it is probable that a combination of the mechanisms proposed acted together to promote derailment of the trailing wheelset.

Coupler lateral bump stop detachment

124 Both of the coupler lateral bump stops on the leading vehicle were found detached from the vehicle. They were carried along the track (bouncing and with forward momentum from the train) for a distance of approximately 200 m causing damage to the underframe equipment on all three vehicles.

125 The most significant damage caused by the coupler lateral bump stops was the puncturing of the air suspension surge reservoir, the tearing of the TCA bracket, the holing of the fuel tank and the damage to the final drives. There was nothing significant about the design of these features that made them more susceptible to the effect of impact than those used on other trains and therefore there are no recommendations relating to their design.

126 The design of the mounting arrangement for the coupler lateral bump stops is unique to Class 175 and 180 trains. There has been no report or experience of a coupler lateral bump stop coming loose or becoming dislodged in the past; it is therefore concluded that they were detached as a result of the collision with the landslip.

127 The possible mechanisms that may have generated the force are discussed below.

128 **Self inertia forces** as a result of the accelerations experienced from the impact and during running derailed may have dislodged the coupler lateral bump stops. This is considered unlikely, since the calculations performed by Alstom demonstrate that the mounting arrangement will withstand a proof load arising from a 5 g (49 m/s^2) longitudinal acceleration, the maximum specified in GM/RT2100. All other equipment attached to the vehicle body is designed to withstand this acceleration limit. No other equipment was detached or deformed during the derailment, other than by direct impact. Based on the assumption that it is unlikely that all other equipment was designed to withstand inertial forces significantly in excess of the requirement in the standard, it is considered unlikely that the train experienced this level of deceleration.

129 Incorrect installation could have resulted in bolt retention forces less than intended. There is evidence that bolts were fitted, that the distance between the nut and bolt heads was equal to the thickness of the mounting plate, and there were torque tell-tale witness marks. Based on this, the lack of failure history and the coincidence of detachment with the train colliding with the landslip, it is likely that the coupler lateral bump stops were correctly installed.

130 **Direct impact with hard debris or drag** through the saturated soil may have generated the detachment forces.

131 A projectile calculation performed by Alstom indicates that a relatively small object (1.25 kg) hitting the coupler lateral bumps stop at 160 km/h (100 mph) would be sufficient to dislodge them. Inspection of the leading faces of the coupler lateral bump stops does not show any obvious impact marks. The obstacle deflector would knock the majority of any significant hard debris out of the way. The location of the coupler lateral bump stops (partially protected within the coupler pocket) limits possible debris trajectories. Inspection of the vehicle indicated that the height of the landslip on the right hand side was below the height of the GRP valance. From this it is concluded that the coupler lateral bump stop on that side was at least 250 mm above the height of the landslip debris. Detachment as a result of direct impact with debris is therefore considered unlikely.

132 The magnitude of drag forces on the coupler lateral bump stops is dependent on the projected area. Simplified calculations demonstrate that, considering the maximum projected area, the force generated by pushing through the debris could be sufficient to detach them. However, again there are no obvious impact or flow marks (similar to those seen on the obstacle deflector) on the leading surfaces of the coupler lateral bump stops. Furthermore, since the right hand side coupler lateral bump stop was at least 250 mm above the height of the debris mound, detachment as a result of direct drag is also considered unlikely.

133 The coupler lateral bump stops were found in a relatively clean condition (see Figure 11) when compared with the rest of the front of the vehicle (see Figure 8) and especially considering the state of the equipment and surfaces within the coupler pocket (see Figure 12). This suggests that the coupler lateral bump stops were dislodged early in the incident, before the train ploughed through the debris, however it is not conclusive.

Figure 11: Coupler lateral bump stop in the 'as found' condition

134 **Coupler impacting the coupler lateral bump stops** either as a result of the train body receiving a lateral acceleration due to the asymmetric impact with the landslip and in turn exciting the coupler to accelerate in the lateral direction or as a result of an input force causing the coupler to swing from side to side.

135 The body would have been deflected laterally by the obstacle deflector and the GRP valance hitting the landslip debris mount. The dynamics of this situation made it possible that the coupler oscillated from side to side in the coupler pocket at least once.

Figure 12: Coupler pocket following passage through landslip

136 Alstom identified a load case from GM/RT2100 (table 2, load case w) against which to assess the risk of coupler lateral bump stop detachment as a result of coupler interaction. The load case identified is a vertical force transferred at the coupler together with a transverse force. Alstom's calculations demonstrated that, for the lateral load of 100 kN, the coupler lateral bump stop remains attached. The calculations indicate a shear force, per bolt, at the joint acting to remove the coupler lateral bump stops of 5.6 kN compared with a restraining force of 5.8 kN, although Alstom highlighted conservative assumptions in their calculations which they believe would result in an overestimate of the removing forces. The vertical load is not relevant for this scenario.

137 General guidance (Railway Systems and Vehicles; Part 1: Railway Systems; Royal Institute of Technology, Stockholm; 2001) and approximate calculations suggest that the level of body acceleration required to generate sufficient force to remove a coupler lateral bump stop is of the order of five times that which passengers would find acceptable with respect to comfort (approximately 1 m/s^2 for standing passengers). This and evidence from the CCTV footage would suggest that, although the passengers recognised an incident had occurred, it is unlikely that the train actually experienced the degree of acceleration needed on its own to dislodge the bump stops. The analysis suggests that the accelerations actually experienced may have contributed to the dislodgement, rather than being the sole cause of it.

138 The forward position of the coupler head and, in particular, the low elevation of the electrical head, as shown in Figure 8, exposes it to the risk of impact. The damage to the coupler electrical head indicates that it received a significant input load, either as a result of a hard object impact or drag effect

139 Although proposing a vertical load in combination with the lateral load, the load case in GM/RT2100 does not require consideration of a longitudinal load. It is probable that during this accident there was a sustained longitudinal load applied to the coupler head that in turn acted on the body structure, partly via the coupler pivot and partly via the coupler lateral bump stops. This is thought likely since the end load on the free coupler would probably cause it to be deflected laterally.

140 Further analysis of Alstom's calculation indicates that a longitudinal load on the coupler head of between 55 and 65 kN, alone, would generate sufficient force at the coupler lateral bump stop to overcome the bolting retention force of its mounting arrangement. The load required is dependent on the proportion of the load reacted at the coupler pivot compared to that reacted at the coupler lateral bump stop. The above forces are derived assuming that the proportion taken by the coupler pivot is between 0 and 66 per cent.

141 Alstom advised that the coupler can move up to 10 mm longitudinally without compression of the crashworthiness element in the coupler shank. For the bump stops to be dislodged they need to move back 23 mm in their slots. That they were dislodged may have been as a result of a ratchet effect of a number of impacts by the coupler, possibly combined with release of energy stored in the coupler lateral bump stops rubber components.

142 The damage to the pipework behind the coupler lateral bump stops and the air suspension surge reservoir indicates that the bump stops were ejected with some considerable energy.

143 However, the evidence available does not prove conclusively a single mechanism or combination of mechanisms to be the cause of the coupler lateral bump stop detachment. The analysis in this report hypothesises that coupler shaft contact with the coupler lateral bump stops as a result of a coupler end impact and possible coincidental body lateral acceleration is the most likely cause of detachment. However, other mechanisms discussed above cannot be discounted.

144 Regardless of the actual mechanism that resulted in the coupler lateral bump stops being dislodged it is known that the force required to dislodge them is 5.8 kN, per bolt, in the plane of the mounting plate. Additionally, they were dislodged following a collision in which there was no structural deformation of the cab crashworthiness structure or the coupler retraction facility. Their detachment is likely to have caused the hole in the fuel tank and the subsequent spillage of approximately 1700 litres of fuel.

145 Railway Group Standards and Railway Safety Principles and Guidance require equipment mounted to a vehicle body to remain attached during normal operation and, as far as practicable, in the event of derailments, heavy shunts and minor to medium collisions. Design should take into account the loading conditions encountered in normal running and abnormal conditions depending on their probability and consequence of failure (paragraphs 74 to 76).

146 The 100 kN lateral and vertical load case in GM/RT2100 and GM/RT2190 is included to represent the force exerted by the coupler on the body structure when operating in multiple with an attached unit derailed. The force is derived from one which can be reacted at the wheel-rail interface without resulting in a derailment. This 'jack-knife' scenario should also include a longitudinal load, but this is omitted.

147 Had this been identified at the time of the design the coupler lateral bump stop mounting arrangement would have needed to be more robust or have secondary retention, whilst not compromising its crashworthiness function.

148 There is no evidence that a revised load case of this nature was thought of or used for any analysis undertaken on the coupler lateral bump stop mounting arrangement. There is also no evidence of consideration being given to the question of whether secondary retention should be fitted or not.

149 The root cause of bump stop detachment is therefore considered to be the non-identification of a load case combination now believed to be relevant and its consequential non-application to the design.

Infrastructure damage

150 The derailed wheelset caused extensive damage to the rail fasteners, sleepers and rails over a distance of 1430 m.

151 Most significant were the fractures of the six foot rail. There were eighteen fractures identified, all occurring at Thermit welds. Nine of the fractures were through the complete rail section, seven resulted in loss of rail section at the rail foot and two were partial cracks. No sections of rail head were broken away or detached.

152 Each failure was brittle in nature and caused by the right hand side trailing wheel flange tip impacting the raised collars of the Thermit welds on the outside of the rail foot. Some impact marks were identified on the raised collars at some of the unbroken Thermit welds. Although these did not break as a result of the derailment, some of them did fail when service was resumed over the route. Network Rail did not remove all of the induced defects before reusing the rail sections.

153 None of the *flash-butt welds* or plain rail failed.

154 The above damage is considered commensurate with the derailment. No further consideration was given as the breaks were unlikely to result in the removal of rail head.

Conclusions

Derailment

155 The immediate cause of the derailment was the train running into material deposited on the track as a result of the cutting landslip.

156 The causal factors leading to the landslip were the volume of water flowing through a field drain into the body of the slope, the wet period over the preceding two weeks, and the excessive rainfall during the previous day (Recommendation 1).

157 Discharge from the field drain into the body of the slope may have been as a result of blockage or failure in a carrier drain or because of omission of a carrier drain during the original construction.

158 The root cause of the landslip is that the field drain was hidden from view (Recommendation 2).

159 In addition, the following factors were considered to be contributory:

- the earthworks examination regime does not clearly identify all of the specific examinations to be carried out by different groups of workers, the associated periodicities, and the arrangements for formal reporting (Recommendation 3a);
- the impracticality of implementing all elements of Network Rail's earthworks standard (NR/SP/CIV/065) (Recommendation 3b);
- not including the limitations from the inspection when assigning the risk to the cutting (Recommendation 3d);
- the lack of guidance on the evaluation process (Recommendation 3d); and
- the classification of the cutting as serviceable (low risk) (Recommendation 3e).

Coupler lateral bump stop detachment

160 The immediate cause of the detachment of the coupler lateral bump stops from the train was the slotted mounting arrangement combined with a set of forces generated by the collision with the landslip and the absence of secondary retention. This is the first use of a coupler lateral bump stop mounting arrangement incorporating a slotted design in the UK.

161 GM/RT2100 does not require consideration of this specific scenario and only partially specifies the loading in a separate load case, the 'jack-knife' load case, which does not include a longitudinal load (paragraphs 136 to 139). The root cause is therefore considered to be that the design process did not anticipate a longitudinal element of a load combination similar to that experienced at the coupler head during this accident scenario (Recommendation 4, 5 and 6).

Infrastructure damage

162 The immediate cause of the rail fractures was the impacting of the raised collars of the Thermit welds by the derailed wheel flange tip.

Actions already taken or in progress

Cutting bank

163 **Emergency Works.** The cutting slope has been repaired. The failed material was excavated and removed. The surface was re-graded to allow an eventual slope gradient of 1:2. It was then stepped and a *geotextile separator* installed. This was then filled to between 1 and 2 m with coarse rock fill to achieve re-graded profile of 1:2 and allow for slope drainage through to the cess drain.

164 A V-ditch was constructed at the slope crest as a temporary measure to intercept surface run off water. Slope drains were excavated at three locations to capture significant water flow to assist with drainage.

165 As part of the immediate repair, a temporary carrier drain was connected to the leaking field drain and the flow taken to the cess drain via a pipe and chamber arrangement.

166 **Further improvement works.** In December 2005 a permanent drain was installed at the slope crest with engineered outfalls to the cess drain. This will mitigate the risk of future failures of a similar kind, by locating, intercepting and capturing field and surface water drainage.

167 **Monitoring.** Two bore holes were sunk and a *piezometer*, *inclinometer* and survey targets installed to indicate any future degradation of the cutting.

168 Network Rail have commissioned a study into factors contributing to earthflow failures.

Track

169 All damaged sleepers were replaced by wholesale renewal. The damaged rails were assessed and reused after replacement of all broken and cracked rail sections with plated-in closure rails, pending availability of new rail for total re-railing. The track was reopened with an Emergency Speed Restriction (initially 50 mph (80 km/h)) until the full repairs could be carried out. Subsequent Thermit weld failures required this to be reduced to 5 mph (8 km/h), whilst the cracked sections were plated, before being raised back to 20 mph (32 km/h). The damaged rails have now been renewed and full speed restored.

Recommendations

170 The RAIB recommendations are directed at those parties who the RAIB believes are best placed to mitigate the identified risks (the implementers). When these parties have considered the recommendations they should establish their own priority and timescale for the necessary work, taking into account their health and safety responsibilities and the safety risk profile and safety priorities within their organisations.[2]

1 Network Rail should ensure that modifications are made to intercept the field drain on Network Rail property and discharge via a carrier drain into an engineered drainage system with sufficient capacity to handle the additional flow (paragraphs 113 and 156).

2 Network Rail should identify priority cutting slopes prone to earthflow failure due to drainage flows from neighbouring property. These should be prioritised according to their likelihood of failure (eg on the basis of catchment area, slope angle and history of previous failures) and the consequence on the safe operation of trains.

For priority cuttings, Network Rail should ensure that it understands all associated drainage arrangements, that they are adequate and that their functionality is maintained. Alternatively they should isolate their land from the effects of such drainage flows (eg by implementing engineered collector drains) (paragraphs 111 and 158).

3 Network Rail should review their overall earthwork and drainage examination regime to introduce the five actions listed below:

a. Identify whether reliance is placed on examinations additional to those described in NR/SP/CIV/065 in managing the risk associated with cuttings. Network Rail should ensure that any additional examinations are clearly identified, undertaken at the correct periodicities and that formal arrangements exist for reporting findings back to the responsible earthworks and drainage engineer (paragraphs 93 and 159).

b. Ensure that, as far as practicable, the actions required to identify precursors to cutting failures can be completely and correctly executed (paragraphs 99 and 159).

Continued

[2] The RAIB addresses its recommendations to *ORR (HMRI)*, the Safety Authority, in accordance with Article 25(2) of the European Railway Safety Directive 2004 (the Directive) and Regulation 12(2)(a) and (b) of the Railways (Accident Investigation and Reporting) Regulations 2005) (RAIR). The RAIB does this to enable *ORR (HMRI)* to discharge its responsibilities under Article 25(2) of the Directive and Regulation 12(2)(a) of the Regulations, namely that they must ensure that all RAIB recommendations addressed to it are duly taken into consideration and where appropriate acted upon by the end implementer.

The end implementer is required under Regulation 12(4)(b) of the Regulations, to provide the Safety Authority with the full details of the measures/actions they intend to take to implement the recommendation and the timescales for securing that implementation. The timeliness of this response to the Safety Authority is dictated by the Safety Authority's duty under RAIR Reg 12(2)(b) to report to the RAIB, without undue delay or within such other period as may be agreed with the Chief Inspector.

c. Ensure that proper allowance is made in any risk assignment to compensate for any lack of accessibility, inadequate information or, the inability to fully complete an examination due to any practical or other constraints (paragraphs 100 and 159).

d. Ensure a consistent and suitable approach to evaluation of the findings from examinations (paragraphs 102 and 159).

e. Introduction of a requirement that a percentage of all marginal and serviceable cuttings are subjected to independent spot checking (paragraphs 103 and 159).

4 RSSB should review the load cases representing credible accident scenarios in Railway Group Standard GM/RT 2100 to ensure that appropriate combinations of lateral, vertical and longitudinal loads experienced at the coupler head are included in the design of trains. This should include a review of the 'jack-knife' load case arising from a derailed unit coupled to a railed unit (paragraphs 146 and 161).

5 Alstom should ensure that the design of the coupler lateral bump stop mounting arrangements for the Class 175 and 180 trains is reviewed against load cases from 'credible accident scenarios', including longitudinal loads experienced at the coupler head (paragraph 146 and 160).

6 Angel Trains Limited should ensure that any modifications to the design made by Alstom in respect of Recommendation 5 above shall, where reasonably practicable, be implemented in the Class 175 and 180 trains that are in their ownership.

Appendices

Glossary of abbreviations and acronyms — Appendix A

AWS	Automatic Warning System
DMU	Diesel Multiple Unit
GRP	Glass Reinforced Plastic
PSR	Permanent Speed Restriction
RAIB	Rail Accident Investigation Branch
RSSB	Railway Safety and Standards Board
S&T	Signalling and Telecommunication
TCA	Track Circuit Actuator
TRV	Track Recording Vehicle

Glossary of terms

Appendix B

Air suspension surge reservoir	Tank accommodating volume changes in the air springs of the secondary suspension system.
Assessment	The determination of the stability of an earthwork taking into account the physical condition of the earthwork.
Automatic Warning System	A system used to give advance warning to drivers of a signal aspect, a temporary speed restriction or a permanent speed restriction.
Ballast	Graded stone sub-base used for drainage and support of the track.
Cab structure	The metal frame giving the cab its strength and providing support for the outer GRP.
Cant	The dimension by which the outer rail on a curve is raised above the inner rail.
Carrier drain	Drain allowing flow from a collector drain through to another carrier drain or a natural sink.
Chain	Unit of linear measurement equal to 22 yards or 20 metres.
Cess	The area either side of the railway immediately off the ballast shoulder.
Cess drain	A drain running in the cess, parallel to the running rails providing a means of removing water from the track system.
Coupler electrical head	A means of connecting two trains electrically.
Coupler head	The front most part of the coupler that provides the connection (mechanical and/or electrical) between two trains.
Coupler lateral bump stops	Features mounted in the coupler pocket, either side of the coupler to limit the coupler's lateral rotational movement.
Coupler pocket	The aperture in the end of the train through which the coupler protrudes which has to be made large enough to accommodate all relative movements between the coupler and the train.
Coupler shank	The cylindrical element of the coupler that transfers the loads from the head to the mounting position on the carbody.
Crashworthiness	A design method that involves designing the train structure so that it is able to perform to a given standard during a collision.
Crest drain	A drain provided at the top of a bank to collect water flowing onto the bank from neighbouring land and direct it to an engineered drain or natural sink.
Cutting	An excavation that allows railway lines to pass through surrounding ground at an acceptable level and gradient.
Diesel Multiple Unit	Train with a diesel power supply distributed along its length.
Down line	The railway line that is predominantly used by trains travelling in the direction away from London.

Earthflow	A landslip resulting from slow to rapid flow of saturated soil and debris in a semi viscous, highly plastic state.
Earthwork	An embankment, cutting or natural slope.
Evaluation	An appraisal of all relevant information and circumstances relating to an earthwork including its condition, use and location to establish whether action is required to ensure that the level of safety and serviceability of an earthwork remain acceptable.
Flange tip	The crown of the larger diameter element of the wheel.
Flash-butt welds	A technique for joining segments of metal rail or pipe in which segments aligned end to end are electronically charged, producing an electric arc that melts and welds the ends of the segments.
Formation	Material provided between the ballast and the subgrade to either increase or reduce the stiffness of the subgrade or to prevent overstressing.
Four foot	The area between the inner running faces of a pair of rails.
Geotextile separator	A flexible, porous textile placed between dissimilar materials so that the integrity and functionality of both materials remain intact, while letting water to pass between them.
Glacial till	Geological deposit consisting of mixture of clay, sands and rocks of varying size.
Inclinometer	An instrument used by surveyors in order to measure an angle of inclination or elevation.
Landslip	A slide of a large mass of dirt and rock down a mountain or cliff.
Load Case	The requirements against which an item is designed.
Marginal	The mid-risk categorisation (between poor and serviceable) of an embankment, cutting or natural slope in accordance with NR/SP/CIV/065.
Obstacle Deflector	A device fitted to the front of trains to encourage any obstacles on the track to move sideways in the event of a collision.
Permanent Way	The track structure which includes rails, sleepers, ballast, blanketing material and drainage.
Piezometer	A measuring instrument for measuring high pressures.
Poor	The highest risk categorisation of an embankment, cutting or natural slope in accordance with NR/SP/CIV/065.
Rail fastenings	General name for devices that are used to rigidly fix rails to sleepers.
Railway Group Standards	These are technical and operational standards which set out requirements for system safety and safe working.

Railway Safety Principles and Guidance	A document produced by ORR (originally HMRI) presenting advice to those involved in the design and construction equipment capable of affecting the safety of the railway.
Raised collars	Elevations left on the foot of the rail following the Thermit welding process.
Rule Book	Book documenting the rules by which all personnel working on railway property must abide, also incorporating those for the safe operation of the network.
Scar face	The surface within the bank that is left exposed following a landslip.
Serviceable	The lowest risk categorisation of an embankment, cutting or natural slope in accordance with NR/SP/CIV/065.
Signalling and telecommunications	General term referring to all control and communication systems on the railway.
Six foot	Space between two sets of tracks (which may be wider then six feet).
Sleeper	Wood, concrete or steel object which holds the rails apart and supports the track on the ballast.
Slope crest	The top of a cutting slope.
Slope toe	The bottom of a cutting slope.
Stability risk	An indication of the margin to failure that a bank has in a given condition.
Survey targets	Devices used to measure movement of land.
Tell-tale	A device to indicate movement of a static arrangement.
Territory Earthworks and Drainage Engineer	Asset steward for all earthworks in a Network Rail Territory.
Toe heave	A bank failure where the bottom of the bank is lifted up.
Track Circuit Actuator	A device fitted to some vehicles to improve the operation of track circuits.
Thermit	A trademark used for a welding and incendiary mixture of fine aluminium powder with a metallic oxide, usually iron, that when ignited yields an intense heat.
Track Recording Vehicle	A train fitted with equipment to automatically measure the condition of the track.
Train data recorder	A system which records key vehicle parameters and stores them in a secured location that is design to withstand the effects of accidents. It is similar to the ‘black box’ used on airplanes.
Trailing wheelset	The combination of two wheels and axle at the rear of the bogie in accordance with the direction of travel.

Translational failure	The downward and outward movement of slope-forming materials.
Underframe	The underneath of the train body to which equipment is attached.
Up line	The railway line that is predominantly used by trains travelling in the direction towards London.

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