RAIB

Rail Accident Investigation Branch

Rail Accident Report

Freight train derailment at Heworth, Tyne and Wear
23 October 2014

Report 16/2015
September 2015

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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Freight train derailment at Heworth, Tyne and Wear, 23 October 2014

Contents

Summary

At about 15:25 hrs on 23 October 2014, a freight train derailed just after passing through Heworth station on the railway line from Sunderland to Newcastle. It was travelling at 51 mph (82 km/h) when the leading wheelset of the tenth wagon derailed on track with regularly spaced dips in both rails, a phenomenon known as cyclic top. The train continued for about 1.4 miles (2.3 km) towards Newcastle where it was stopped by the signaller, who had become aware of a possible problem with the train through damage to the signalling system. By the time the train stopped, both of the wagon's wheelsets were derailed and its suspension was damaged. There was also damage to the track, points, signalling cables and signalling equipment that the derailed wheelsets had run over. There were no injuries.

The immediate cause of the derailment was a combination of a loss of damping within the suspension on one corner of the wagon and dips in the track. The wagon was found to have a worn suspension component on its leading right-hand corner which made the leading left-hand wheel susceptible to unloading and lifting up when responding to dips in the track. The wagon's maintenance regime had not identified this worn component. The excessive wear was probably due to a problem with the alignment of the wheelset within its suspension. The severity of the dips in the track required Network Rail to impose an emergency speed restriction but no such restriction had been put in place. The dips formed continually due to water in the track not draining away and although the track inspection regime had identified this defect many times, often no repair took place. Occasionally the local Network Rail track maintenance team carried out manual repairs but these were ineffective.

An underlying cause was that the local track maintenance team was unable to cope with the volume of work it had to do. This was due to a combination of reduced numbers of track maintenance staff over a long period of time, changes to the arrangements for working safely while on the track, restrictions on gaining access to the track at Heworth and changes to how the track was inspected. A further underlying cause was that Network Rail's audit and self-assurance processes did not alert senior management to the extent of non-compliances to maintenance processes or trigger earlier action to resolve persistent problems affecting the track assets in the local track maintenance team's area.

The RAIB has made five recommendations. One recommendation is directed to Freightliner and covers mitigating the risk of this type of wagon's ride performance being degraded by worn suspension components. The other four are directed to Network Rail and cover:

- investigating why water is not draining from the track where the train derailed;
- reviewing whether defects found by the track inspection regime are accurately recorded and that corresponding repair work is planned;
- understanding and taking action to address why the track assets in this area consistently have high numbers of defects; and
- understanding and taking action to address why its management arrangements allowed the non-compliances to processes for track maintenance found by this investigation to go undetected.

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 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Sources of evidence used in the investigation are listed in appendix C.

The accident

Summary of the accident

3 At about 15:25 hrs on 23 October 2014, a freight train derailed just after passing through Heworth station on the railway line from Sunderland to Newcastle (figure 1). It was travelling at 51 mph (82 km/h) when the leading *wheelset* of the tenth wagon derailed on track with regularly spaced dips in both rails, a phenomenon known as cyclic top.

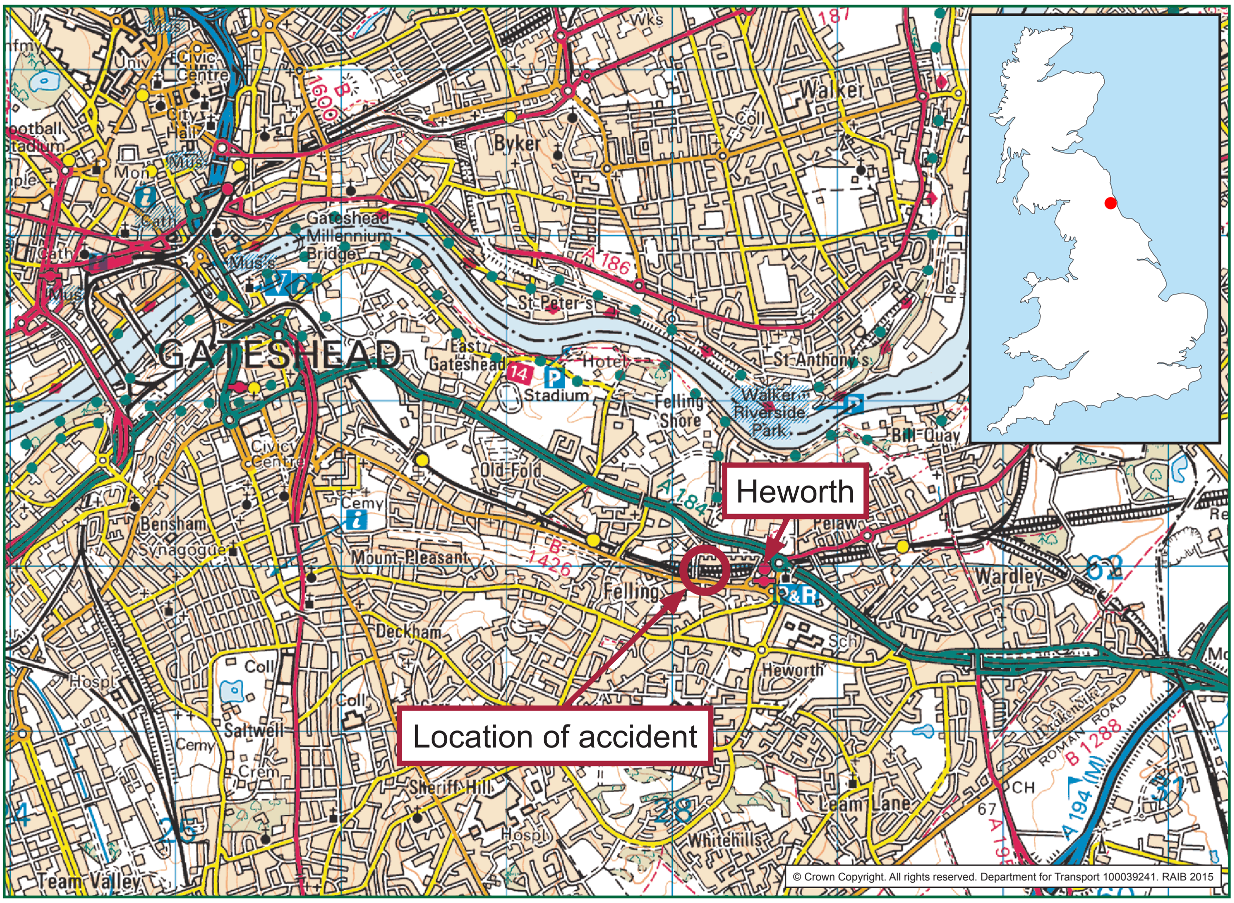


Figure 1: Extract from Ordnance Survey map showing location of accident

4 The train continued as its driver was unaware of the derailment, although the driver applied the brakes to slow the train down as it approached Newcastle. By the time it reached St James Bridge junction (figure 2) the trailing wheelset on the tenth wagon had been pulled into derailment. The wagon's derailed wheels caused damage to the track and signalling equipment, which alerted the signaller working at Tyneside signalling centre to a possible problem with the train. The signaller then took action to stop the train using signals. As the train approached Park Lane junction while travelling at about 7 mph (11 km/h), the driver saw the next signal unexpectedly change to display a red *aspect* and he brought the train to a stand in response. The train had run derailed for about 3 minutes 50 seconds, covering a distance of 1.4 miles (2.3 km).

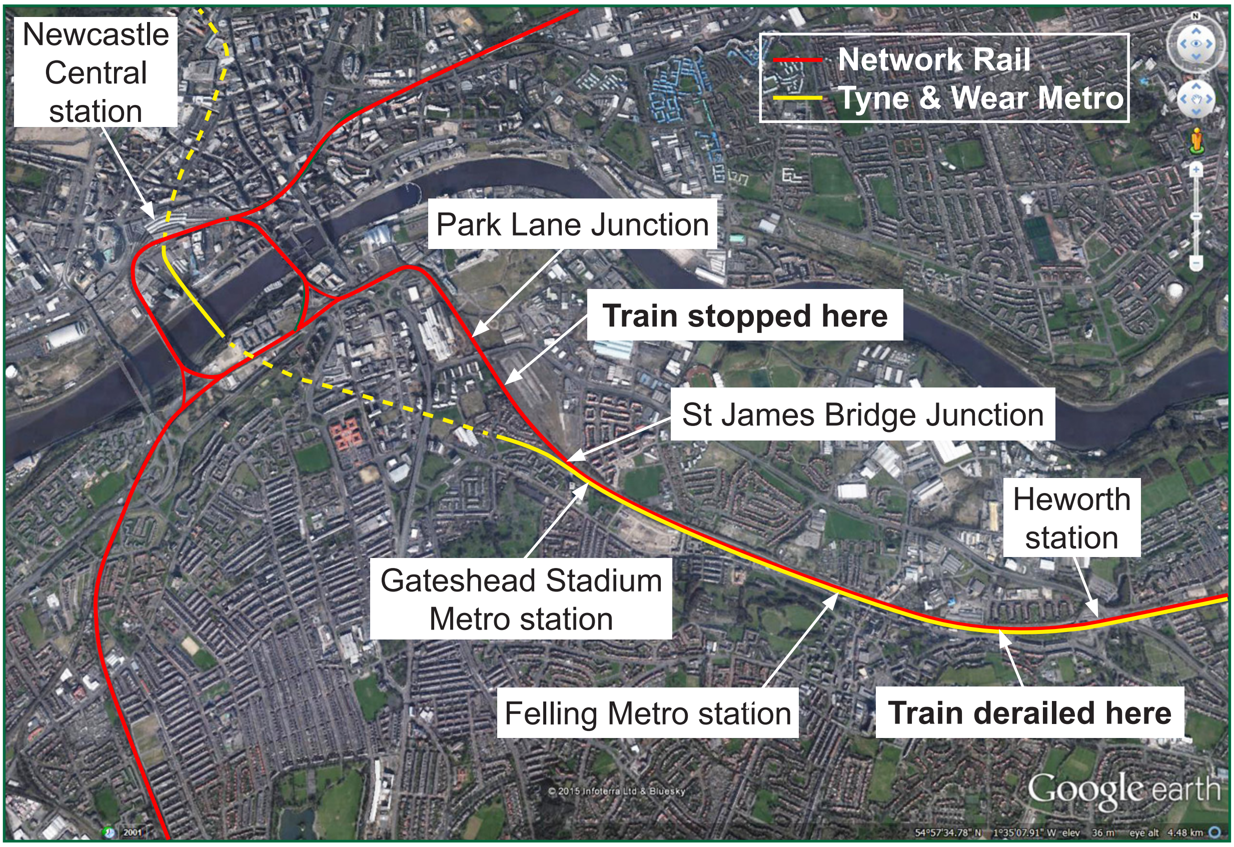


Figure 2: Track layout from the point of derailment through to the train's stopping point

5 No one was hurt in the accident and no other trains passed the derailed train on the adjacent Network Rail line or Tyne and Wear Metro lines. The Network Rail line remained closed until about 07:45 hrs on 24 October for recovery of the derailed wagon, temporary repairs to the track and repairs to the other damaged infrastructure. The line was reopened with a 20 mph (32 km/h) speed restriction over the point of derailment.

Context

Location

6 The derailment occurred on the *Down Sunderland* line between Sunderland and Newcastle, at 99 miles and 253 yards (from a zero reference at Leeds station), which is part of Network Rail's *London North Eastern (LNE) Route*.

7 At this location, the two track railway comprises the *Up Sunderland* and Down Sunderland lines (figure 3). The permitted speed for trains on both lines is 70 mph (113 km/h), although the maximum speed for the type of train that derailed was 60 mph (97 km/h). The Down Sunderland line is not electrified but it runs parallel with the two track railway of the Tyne and Wear Metro, which is electrified with 1500 Volt direct current (DC) overhead line equipment.

8 The derailment happened in a cutting, where the track is on a right-hand curve (in the train's direction of travel) of about 1750 metres radius and on a falling gradient of about 1 in 175 (0.57%). The track on the Down Sunderland line consists of *continuous welded rail* on concrete *sleepers*. Signalling in the area is controlled from the Gateshead *workstation* at Tyneside signalling centre.

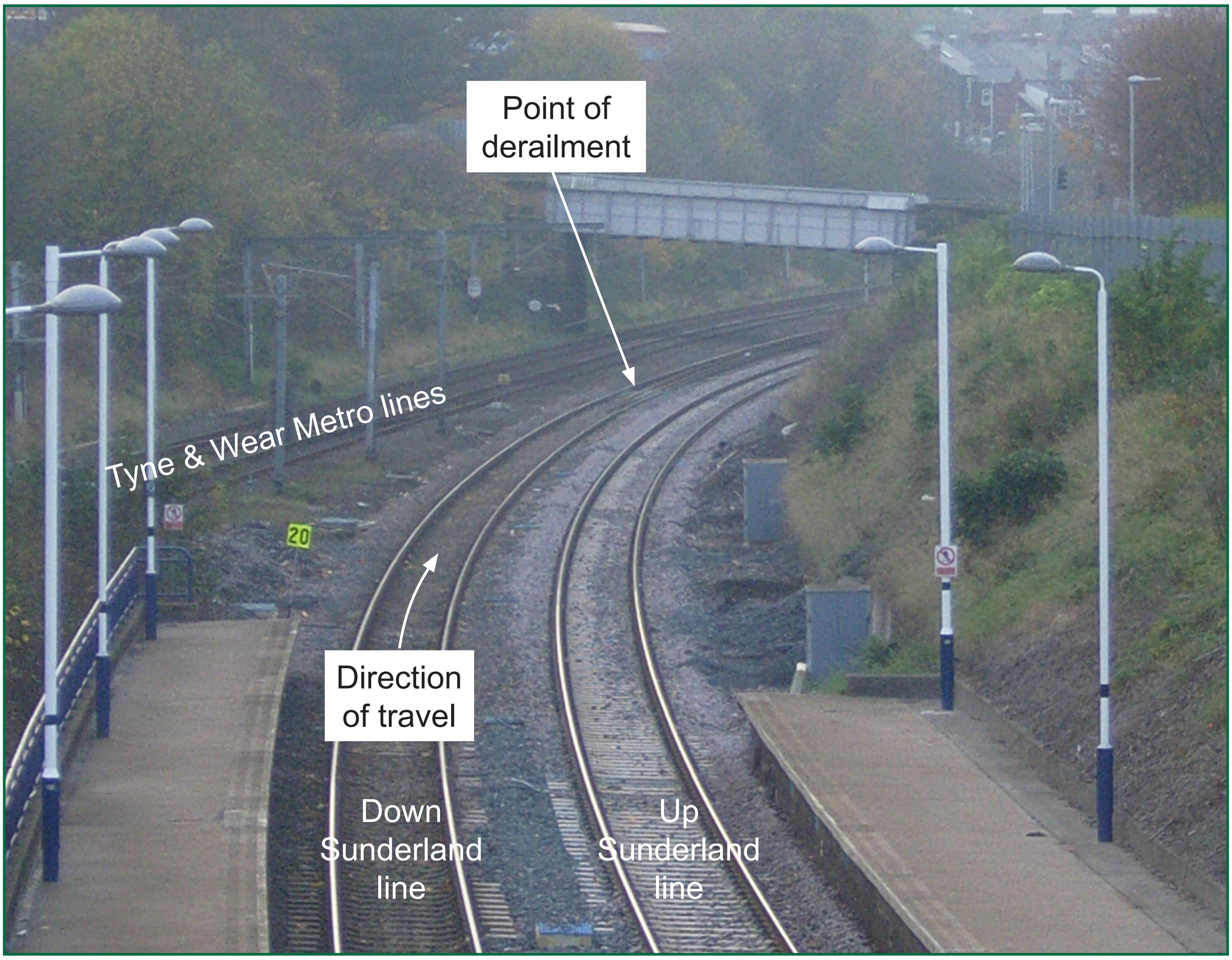


Figure 3: Location of the derailment

Organisations involved

9 Network Rail owns, operates and maintains the infrastructure, including the track where the derailment occurred. The freight train was operated by Freightliner Heavy Haul, which also owns the wagon and employs the driver. Freightliner Heavy Haul was also the *Entity in Charge of Maintenance* (ECM) for the wagon.

10 Both of these organisations freely co-operated with the investigation.

Train involved

11 The freight train that derailed, reporting number 6S26, was the 14:47 hrs service from Seaham Harbour, near Sunderland, to Dunbar cement works at Oxwellmains. It consisted of a class 66 diesel-electric locomotive, 66 616, hauling 25, two-axle, PCA cement tank wagons (the PCA wagon type is described in more detail in paragraphs 24 and 25). All of the wagons were empty. The wagon that derailed was number 10769 (figure 4).

Figure 4: PCA wagon 10769 that derailed at Heworth

Staff involved

12 Staff based at Network Rail's Newcastle maintenance depot were responsible for maintaining the track where the derailment occurred. The Newcastle *Track Section Manager* (referred to as TSM1) had worked for 11 years on track maintenance in the Newcastle area, but had only been in the post since September 2014. The person previously in this post (referred to as TSM2) had 16 years' experience; 3 years as the Track Section Manager and 6 years as the Assistant Track Section Manager before that. The *Track Maintenance Engineer* for Newcastle (referred to as TME1) had 12 years' experience working in track related roles, and had been in the post since June 2013. The person previously in this role (referred to as TME2) had been a Track Maintenance Engineer for about 10 years, including for the Newcastle area from 2008 to 2013.

13 Freightliner staff based at Dunbar were responsible for maintaining the wagon that derailed. They were experienced in maintaining PCA wagons.

External circumstances

14 It was daylight at the time of the derailment. The local weather was dry, with a temperature of about 16°C (based on data at the nearest weather station 2.7 miles (4.3 km) away). There were no external circumstances which directly affected the derailment although water had previously affected the condition of the track (paragraph 85).

The sequence of events

Events preceding the accident

15 The wagons that formed train 6S26 had earlier travelled from Dunbar to Seaham Harbour laden with cement powder. At Seaham Harbour, the wagons were unloaded and then shunted so that the locomotive could run round its train. After its pre-departure checks[1] were completed, the train left the sidings at Seaham Harbour at 14:42 hrs, five minutes early.

16 At 15:03 hrs, train 6S26 passed through Sunderland station and onto the railway line shared with Tyne and Wear Metro trains between Sunderland and Pelaw, which has a maximum speed of 30 mph (48 km/h) for freight trains. The train was running on time. About 20 minutes later it passed Pelaw Metro junction, where shared running with the Tyne and Wear Metro ends, and the train began accelerating under green signals. At 15:25 hrs, it passed through Heworth station and soon after arrived at 99 miles 239 yards on the Down Sunderland line, which is where the cyclic top started.

Events during the accident

17 The train passed over the section of track with cyclic top while travelling at 51 mph (82 km/h). The locomotive and first nine wagons did not derail but the leading wheelset of the tenth wagon did. The following 15 wagons did not derail.

18 Marks found on the head of the left-hand rail show that the flange of a wheel had climbed onto the top of this rail at 99 miles 253 yards (figure 5). The flange ran along the head of the rail for 10.3 metres before the wheelset derailed to the left. At this point the right-hand wheel derailed into the *four foot.*

19 The train continued with the tenth wagon's leading wheelset running derailed. There was no indication to the driver of a problem with the train, so he applied and released the train's brakes to slow the train down as it approached Newcastle. During this time the trailing wheelset of the tenth wagon was also pulled into derailment.

20 The derailed wagon was kept generally in line by the couplings of the adjacent wagons. The wheels were running on top of the concrete sleepers (evidenced by the closed circuit television (CCTV) footage of the train passing through Felling – see figure 6). The derailed wheels struck a set of *points* at St James Bridge junction at 100 miles 506 yards while travelling at about 13 mph (21 km/h), causing damage to the points and also to the wagon's suspension.

Events following the accident

21 As the train approached Park Lane junction at 7 mph (11 km/h), the driver stopped his train in response to the signal for the junction ahead changing from a single yellow to a red aspect. The signaller had noticed unusual indications on the workstation after the passage of train 6S26, consistent with signalling equipment being damaged, and had put the signal in front of train 6S26 back to red to stop it.

[1] The pre-departure check is a physical examination of the train to ensure that the train is safe to depart and includes checks for the wagons' brakes, couplings, etc. Full details are provided in Working Manual for Rail Staff Freight Train Operations, Section C - Principles of Safe Freight Train Operation, reference GO/RT3056/C.

Figure 5: The path of the flange marked out on the head of the left-hand rail (image courtesy of Network Rail)

Figure 6: CCTV image of the derailed wagon passing Felling Metro station (image courtesy of DB Regio Tyne and Wear Metro)

22 Once stopped, the driver called the signaller. The signaller explained that the workstation appeared to show that signalling equipment had been damaged after the passage of this train and asked the driver to examine his train. The driver walked alongside his train and found the derailed wagon. He reported what he had found to the signaller.

23 Staff from Network Rail, Freightliner and the RAIB attended the site. Wagon 10769 was re-railed by 02:58 hrs on 24 October and the train was moved at very slow speed to Tyne Yard where wagon 10769 and the wagon either side of it were detached. Overnight, Network Rail completed repairs to damaged track components, repaired the damaged points equipment at St James Bridge junction, and replaced cables and other signalling equipment that had been damaged. Network Rail also made a temporary repair to the track on the Down Sunderland line where the wagon had derailed, by depositing new ballast on top of it and then using a *tamper* to lift up the track and consolidate the ballast under the sleepers. The line was reopened at 07:44 hrs on 24 October, with a 20 mph (32 km/h) speed restriction in place over the cyclic top site (due to its degraded track geometry).

Key facts and analysis

Background information (Wagon)

PCA wagon

24 The PCA wagon that derailed (figure 4) was one of a batch of cement tank wagons that were built by British Rail Engineering Limited (BREL) in Ashford in 1981. Other batches were built from 1981 up until 1987. In November 2007, Freightliner Heavy Haul became responsible for operating and maintaining the PCA wagon fleet and in 2015 the fleet was being operated out of Hope (Derbyshire) and Dunbar (East Lothian). The wagons are also maintained at these locations.

25 Freightliner's PCA wagons are two-axle wagons and each consists of a frame that supports a mild steel tank which is used to carry cement powder. These wagons have a gross weight of 51 tonnes when laden, and weigh about 13 tonnes when empty. They are fitted with 'Gloucester' pedestal suspensions, which are a type of floating pedestal suspension (see paragraphs 26 to 28). Two types of this suspension are fitted to Freightliner's PCA wagons; the 'Mark 2' on older wagons and the 'Mark 4' on newer wagons.

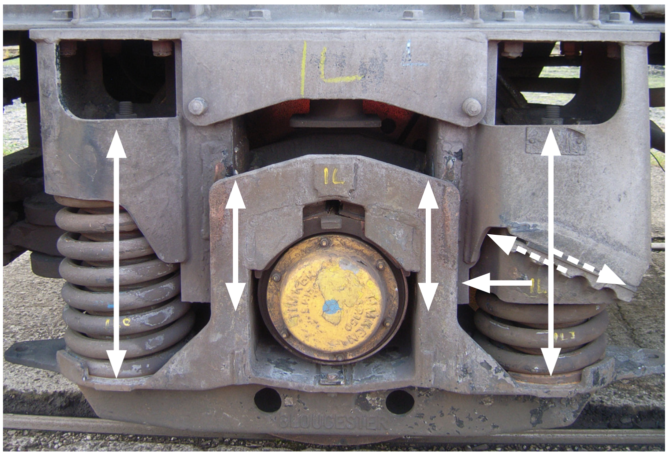
'Mark 2' Gloucester pedestal suspension

26 The 'Mark 2' Gloucester pedestal suspension was fitted to the PCA wagon that derailed at Heworth (figure 7). It was designed and manufactured by the Gloucester Railway Carriage and Wagon Company. This suspension unit has a *pedestal* (also known as an axle horn guide) bolted to the underside of the frame. A *saddle* houses the axle bearing and slots into the pedestal.

27 The saddle supports primary, secondary and inner or 'cup' springs. The spring arrangement is fixed with a retaining pin known as an 'anti-separation pin' running through the centre. The springs are located between the pedestal and the saddle and are compressed by the weight of the wagon.

28 On the inner side of the saddle, a *damper pot* is located between the top of the springs and the pedestal. The weight of the wagon and its payload at each corner acts upon a pair of wedges between the pedestal and the damper pot. The downwards force acting on the damper pot creates a horizontal force through the wedge which pushes a *damper pad*, housed inside a hole in the pedestal, against a friction liner plate on the saddle, to damp the vertical movement of the saddle. The damping force thus changes according to the load on that corner of the wagon.

29 The 'Mark 2' suspension was replaced on PCA wagons built from 1984 onwards by the 'Mark 4' Gloucester pedestal suspension. The 'Mark 4' suspension (which is also fitted to the PHA wagons referred to in paragraphs 185 to 190) is very similar in design and operation to the 'Mark 2' suspension. The main difference is that the pedestal for the 'Mark 4' suspension is cast as one piece when manufactured. The damper pad that sits within the pedestal is also of a different design. The saddle, damper pot and springs are common to both the 'Mark 2' and 'Mark 4' suspensions.



Forces within the suspension

Wedge between pedestal and damper pot to convert vertical force into a horizontal force which damps movement of the saddle

The suspension components

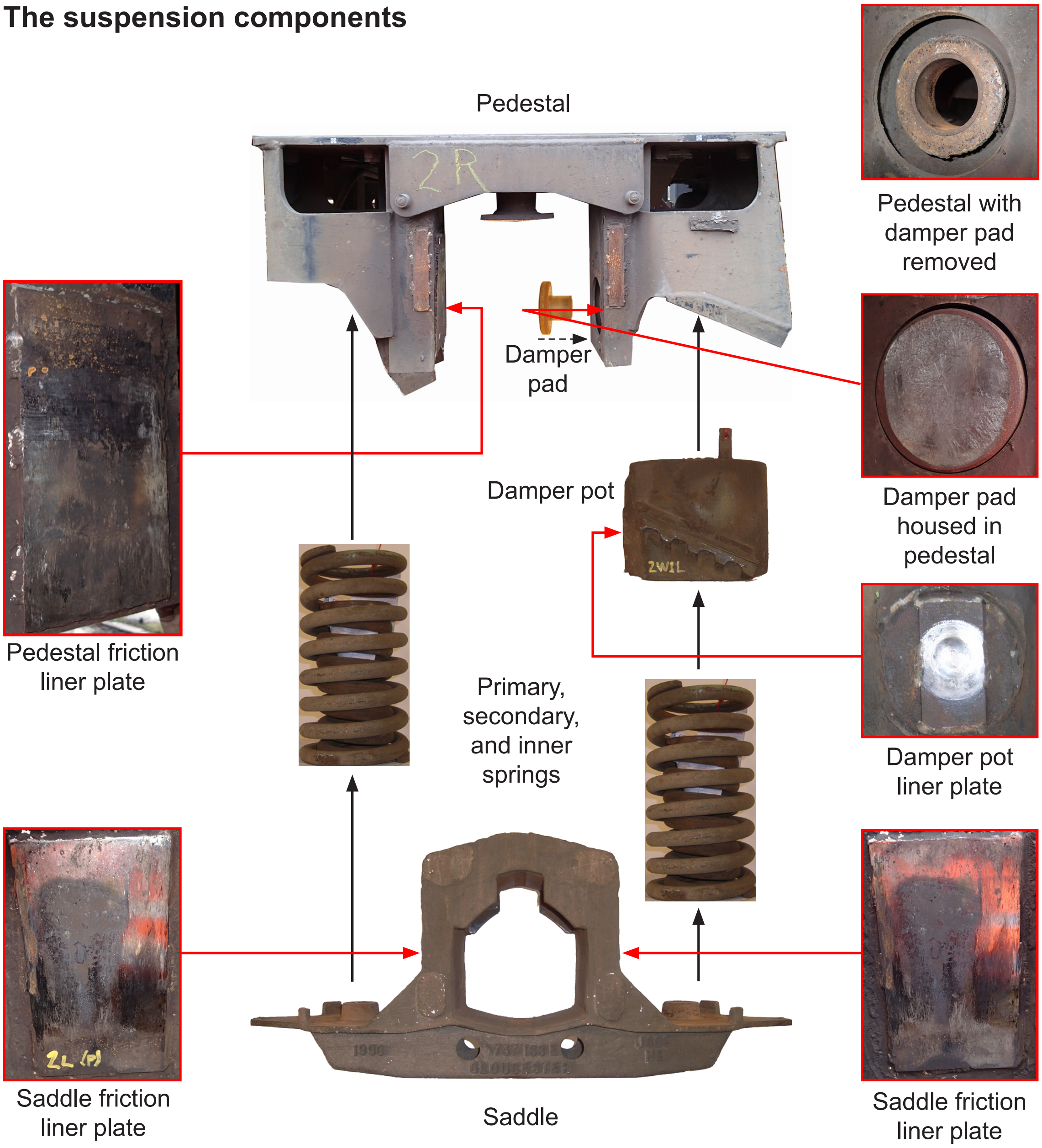


Figure 7: The 'Mark 2' Gloucester pedestal suspension

Background information (Track)

The Newcastle Track Maintenance Engineer's area

30 The Track Maintenance Engineer is the Network Rail manager who is responsible for the delivery of track maintenance within a defined area, so that the track is safe for the passage of trains. Each Track Maintenance Engineer is responsible for the maintenance strategy for the track assets in their area and is required to inspect all of their track assets at least once every two years. These inspections are used to review the condition of the track, check the quality of the maintenance being delivered and to identify any longer term needs such as track renewals. The Down Sunderland line at Heworth falls into the geographical area that the Newcastle Track Maintenance Engineer is responsible for (figure 8). This area includes about 335 miles (539 km) of track, and about 550 sets of points.

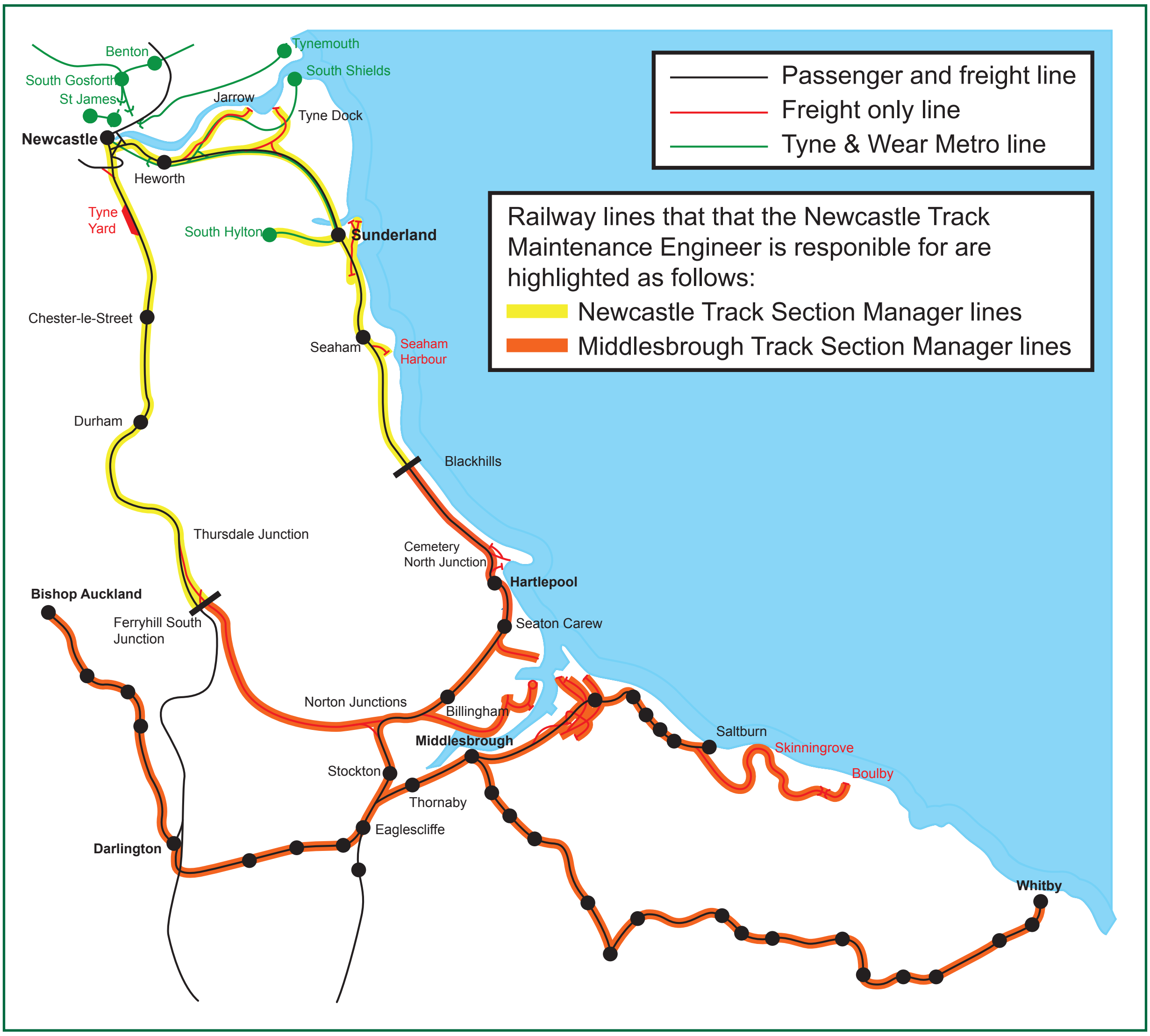


Figure 8: The Newcastle Track Maintenance Engineer's geographical area

31 Track Section Managers report directly to the Track Maintenance Engineer and are responsible for managing the day-to-day maintenance of the track. They are local Network Rail managers who lead a team of track maintenance staff and are responsible for:

- ensuring that their staff complete track inspections within the timescales required by the track inspection regime;
- prioritising the maintenance work to be done;
- checking the quality of the work that is completed; and
- monitoring that their staff are complying with standards.

32 In the Newcastle area, the Newcastle and Middlesbrough Track Section Managers report to the Track Maintenance Engineer. The geographical area that each of these Track Section Managers is responsible for is shown in figure 8. Heworth falls within the Newcastle Track Section Manager's area, which includes about 140 miles (225 km) of track and about 250 sets of points.

Track inspection regime

33 The track in the Down Sunderland line where the derailment occurred was classified by Network Rail as category 3. This category, which is based on the permitted speed and tonnage (ie the number of trains and their weight) passing over the line, is used to define the track inspection regime. In accordance with Network Rail's standards for track maintenance, NR/L2/TRK/001/mod02 'Track Inspection' and NR/L2/TRK/001/mod11 'Track geometry – Inspections and minimum actions', the Down Sunderland line was subject to the following inspection regime:

- A *basic visual inspection* to identify any immediate or short term actions that are required, which is carried out by track maintenance staff on foot once every four weeks (often referred to as a 'track patrol');
- an inspection by the Track Section Manager on foot once every 16 weeks;
- an inspection by the Track Maintenance Engineer on foot once every two years;
- an inspection by the Track Section Manager from the cab of a train once every 26 weeks;
- an inspection by the Track Maintenance Engineer from the cab of a train once every year; and
- track geometry recording by a *track geometry recording train* once every 16 weeks.

34 Records show that in practice, due to other parts of the Down Sunderland line being classified as category 2 track, some inspections over the point of derailment were more frequent. Cab ride inspections by the Track Section Manager took place every 13 weeks, cab ride inspections by the Track Maintenance Engineer took place every 26 weeks, and track geometry recording took place about once every 12 weeks.

Plain Line Pattern Recognition train

35 Network Rail is introducing train based technology to do routine basic visual inspections of plain line track instead of using its staff to walk the track. This technology, known as *Plain Line Pattern Recognition* (PLPR), can be used for visual inspections of continuous welded rail fitted with common types of rail *fastening*. The current version of PLPR cannot be used on continuous welded rail with other types of rail fastening, other types of track such as jointed track, or places where rails are joined (eg at points).

36 Each train fitted with PLPR technology has a series of line-scan, three dimensional (3D) and thermal imaging cameras that capture images of the track components while running up to speeds of 125 mph (201 km/h). Software is used to process the captured images to recognise the track components and identify any associated defects. Defects that are found are listed in a report. The train also records the track geometry while it is running, in the same way that a track geometry recording train does. Again, any defects that are found are listed in a report.

37 Before the derailment occurred at Heworth, trains fitted with PLPR technology were being trialled by running over the Down Sunderland line at a frequency of up to once every two weeks, and the last PLPR recording over the point of derailment was on 11 October 2014.

Cyclic top

38 Cyclic top is a regular series of alternate high and low spots in a track. At certain speeds, this can cause *resonance* in the suspension of some types of rail vehicles. In extreme cases, the resulting bouncing or pitching motion can cause the vehicle to derail when one of the wheels becomes unloaded allowing its flange to either climb or jump onto and over the rail head.

39 The severity of the high and low spots in the track which combine to make up cyclic top may not be identified during a visual inspection if there are *voids* under the sleepers. As a train passes over voids, its weight pushes the track down into the space under the sleepers and the track recovers to its former geometry afterwards. This may cause the track geometry to appear visually better than it is, but to exhibit more severe cyclic top under load. The only reliable means to identify and measure the severity of cyclic top is by running a track geometry recording train over the section of line. Network Rail's records show these trains were running over the Down Sunderland line about once every 12 weeks, in addition to the recordings by PLPR trains.

40 Network Rail has a fleet of track geometry recording trains. On-board systems analyse the track geometry data as it is captured to identify discrete faults and generate reports which list information such as the type of defect, its size and its location. These are sent to the part of Network Rail responsible for maintaining that section of line so that the Track Section Manager can implement the action required by NR/L2/TRK/001/mod11.

41 Vertical track geometry faults are reported as either top or cyclic top defects, where top is the term commonly used in track maintenance when referring to a rail's vertical profile. A top defect report relates to the size of a single dip in the height of a rail and its location, whereas a cyclic top track defect report relates to a series of regularly spaced dips in one or both rails.

42 Appendix E provides further information about how Network Rail measures cyclic top defects and the actions it requires its staff to take when a cyclic top defect is found. This appendix also describes how Network Rail measures the overall quality of its track with respect to its vertical profile and the repair methods that its staff can use to correct or improve the track's vertical geometry.

Identification of the immediate cause

43 The leading left-hand wheel of PCA wagon 10769 climbed onto the head of the rail and derailed.

44 Marks on the head of the left-hand rail of the Down Sunderland line showed a wheel flange had climbed onto and run along the top of the rail for 10.3 metres before derailing to the left (figure 5).

Identification of causal factors

45 The derailment occurred due to a combination of the following causal factors:

a. The wheel on the leading right-hand corner of wagon 10769 was not sufficiently damped due to a worn damper pad in its suspension, which made the leading left-hand wheel on the wagon susceptible to unloading when responding to changes in vertical track geometry (paragraph 46).

b. The ballast on the approach to the point of derailment on the Down Sunderland line was heavily contaminated with slurry, resulting in *wet beds* and vertical track geometry faults that required maintenance action, including a cyclic top defect which should have resulted in the imposition of an *emergency speed restriction* (paragraph 74).

Each of these factors is now considered in turn.

The condition of the wagon's suspension

46 The wheel on the leading right-hand corner of wagon 10769 was not sufficiently damped due to a worn damper pad in its suspension, which made the leading left-hand wheel on the wagon susceptible to unloading when responding to changes in vertical track geometry.

47 When the RAIB examined wagon 10769 on site, and later at Tyne Yard after it had been re-railed, an 8 mm gap could be seen between the pedestal and saddle friction liner plates on the leading right-hand corner suspension (figure 9). These two plates should be in contact and rub against each other.

48 At Tyne Yard, the wagon was lifted so that its wheelsets could be removed and all of its suspension components examined and measured. Freightliner's maintenance records show that this wagon had last been lifted in January 2014, when all of the suspension components were examined during the wagon's annual *Vehicle Inspection and Brake Test* (VIBT) *maintenance examination*. Freightliner had carried out a six monthly *Planned Preventative Maintenance* (PPM) examination on it on 20 August but as the wagon was not lifted, only those parts of the suspension that could be seen were visually checked.

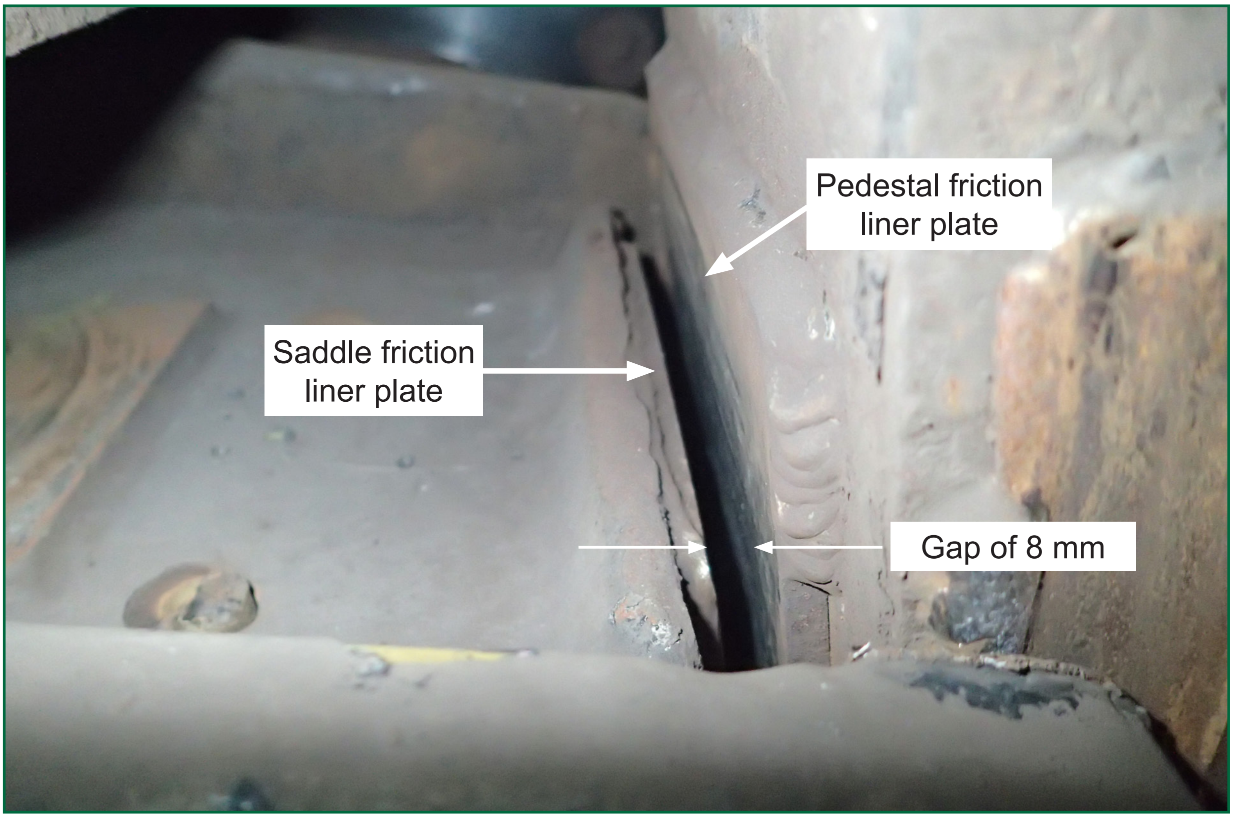


Figure 9: The gap in the suspension on the leading right-hand corner

49 The suspension component measurements on the leading right-hand corner were checked against the limits defined in Freightliner's vehicle maintenance instruction for PCA wagons. Two suspension components exceeded the limits:

- the depth of wear on the damper pot liner plate was 1.4 mm, exceeding the limit of 1.0 mm; and
- the damper pad was worn to a length of 57.2 mm, exceeding the wear limit of 65.0 mm.

50 The damper pads from the other three corners of the wagon were all inside the permitted wear limit. Figure 10 shows the damper pads from the leading left and right-hand corners, highlighting the difference in the amount of wear.

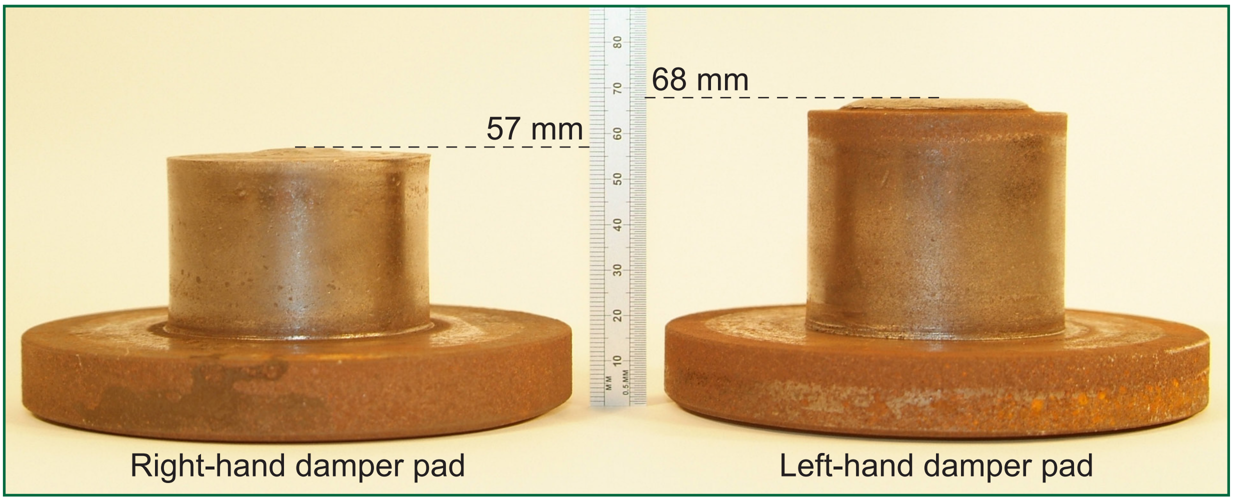


Figure 10: The damper pads from the leading right and left-hand corners

51 The worn damper pad and the gap found between the friction liner plates indicated that there was a loss of damping within the suspension on the leading right-hand corner of this wagon. This in turn would affect how the wagon rode over vertical track geometry faults. In order to gain a better understanding of what effect a loss of damping would have on the wagon's ride performance, dynamic modelling was undertaken using the *VAMPIRE®* computer software simulation package. Further information about the vehicle and track models used for the dynamic modelling is provided in appendix D.

52 The dynamic modelling predicted that when a wagon with a working suspension (ie no loss of damping at all) passed over the track at the same speed that train 6S26 was travelling at when it derailed (paragraph 17), the leading left-hand wheel was fully unloaded due to the vertical track geometry, and the wheel lifted off the rail a small amount (1.4 mm). None of the other wheels were predicted to be fully unloaded. Figure 11 shows that as the amount of damping on the leading right-hand corner was reduced, the wagon's ride performance at its leading left-hand wheel worsened, with this wheel lifting higher and for longer (up to 17 mm over a distance of 3.1 metres). Further simulations to understand the sensitivity of the wagon's ride performance to changes in speed showed the worst ride performance occurred at 50 mph (80 km/h), when there was no damping and a gap between the friction liner plates. These conditions matched those at the time of the derailment. Further details about the results from the dynamic modelling are provided in appendix D.

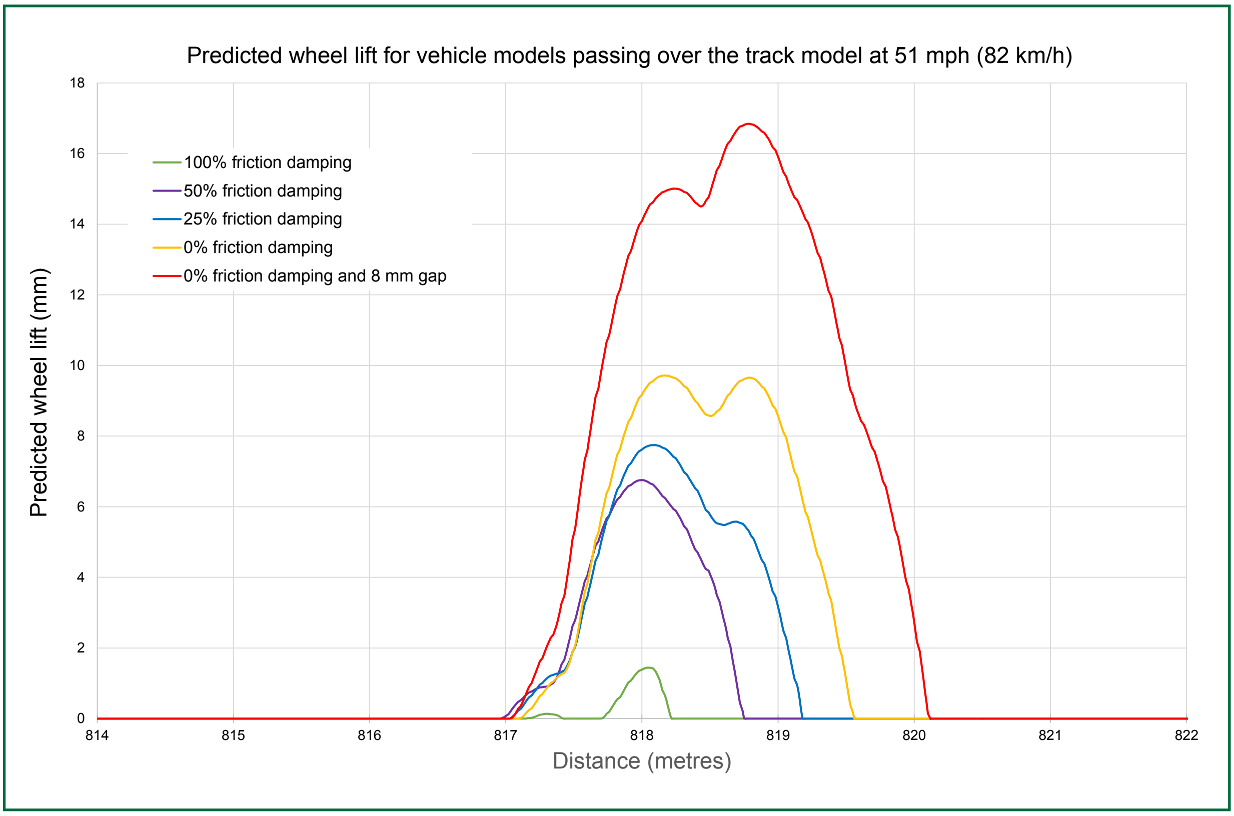


Figure 11: Simulation results for the leading left-hand wheel of vehicle models passing over the track model at 51 mph (82 km/h)

53 After the worn damper pad was found on wagon 10769, Freightliner issued an instruction for a special check to be carried out on its fleet of 153 PCA wagons fitted with the ‘Mark 2’ suspension. The check aimed to look for longitudinal movement of the saddle within the pedestal. It required staff to insert a lever between the saddle and pedestal on the side opposite to the damper pot, and attempt to move the saddle away from the pedestal friction liner plate. It should not move. The check was repeated from the other side and again the saddle should not move. If movement was visible, the amount was measured and recorded.

54 Four wagons were identified with movement in the suspension on at least one corner. Further examinations found two of these wagons had a worn damper pad on one corner; one measured 56 mm, the other 57 mm. On the third wagon, Freightliner found that the bush in the pedestal, in which the damper pad sits, was worn. No fault was found with the fourth wagon.

55 Freightliner also instructed its maintenance staff to remove and measure the damper pads from each suspension every time a wagon underwent its annual maintenance examination (see paragraph 196). Data gathered from 69 wagons between the middle of December 2014 to the end of March 2015 was analysed. Of these wagons, 25 had ‘Mark 2’ suspensions and the remaining 44 had ‘Mark 4’ suspensions. None of the 100 damper pads from the ‘Mark 2’ suspensions measured 65 mm or less and only one measured 66 mm. The rest measured 67 mm or greater showing that high levels of damper pad wear in between annual examinations are not a common problem within the fleet of PCA wagons with ‘Mark 2’ suspensions. None of the damper pads from the ‘Mark 4’ suspensions were worn beyond their maintenance limit.

56 Figure 12 shows a damper pad used in a ‘Mark 2’ suspension. When in situ within the suspension, the larger diameter end rubs up and down against a friction liner plate welded onto the saddle. The smaller diameter spigot end is in contact with a liner plate welded onto the damper pot.

57 A metallurgical examination was undertaken of the damper pads removed from the leading corners on wagon 10769. This found that while the material specification for the damper pads calls for malleable cast iron to be used, these damper pads were manufactured from nodular (spheroidal graphite) cast iron. Although this material did not meet the specification, it was a satisfactory substitute for the malleable cast iron that was specified.

58 The damper pad specification calls for the smaller spigot end to be hardened to a depth of 4 mm (figure 12). Once this hardened material is worn away, the underlying material that is exposed is softer and will wear much quicker. The depth of hardening on a new damper pad, which has an overall length of 69 mm, corresponds with the wear limit of 65 mm in Freightliner’s vehicle maintenance instruction.

59 The damper pad from the leading left-hand corner was tested and the hardness recorded on the tip of the spigot end exceeded the value required by the specification. It was hardened to a depth of about 3.5 mm, but allowing for 1 mm of wear that was noted, it is likely that the depth of hardening when new would have met the specification.

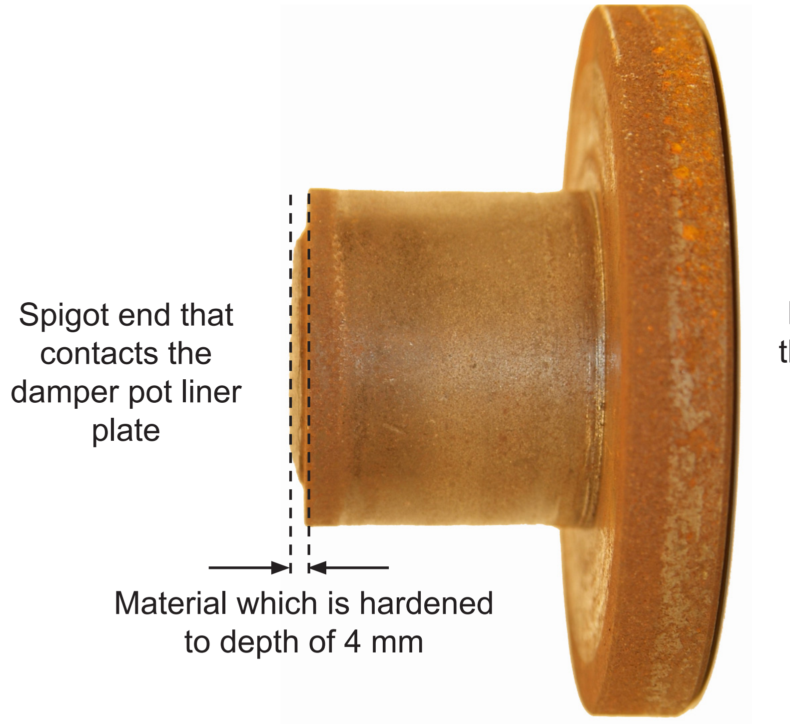


Figure 12: A damper pad used in a 'Mark 2' Gloucester pedestal suspension

60 When the damper pad from the leading right-hand corner was tested, no traces of hardening were found. Almost 12 mm of material had been worn away, exceeding the depth of any hardening. A residual centrally raised portion could be seen on the surface of this wear face (figure 13), which indicated that it had been hardened at manufacture. If this was not the case, then it is likely that the worn end would have been flat. However, the effectiveness of any hardening at manufacture could not be confirmed, as this material had worn away. The opposite wear face on the damper pot also indicated that the damper pad had been hardened.

Figure 13: The wear faces on the damper pad from the leading right-hand corner

61 The scuff marks on the larger diameter end of the damper pad are shown in figure 13. These marks are aligned in different directions and indicate that the damper pad had been rotating while in service. Evidence of rotation could also be seen on the spigot end of the damper pad and on the damper pot it wore against. This rotating movement would have worn away the material at the spigot end of the damper pad.

62 While the possibility that the damper pad was defective cannot be discounted, the available evidence indicates that this was unlikely. Instead, it is likely that all of the hardened material at the damper pad's spigot end had worn away due to it rotating in service. Once the hardened material was worn away, the rate of wear significantly increased, resulting in 12 mm of wear in a 9 month period. This occurred because:

- a damper pad that was already close to the wear limit was installed at the last VIBT examination (paragraph 63); or
- a problem with the alignment of the leading wheelset within its suspension caused excessive damper pad wear while also increasing the propensity of the wagon to derail (paragraph 67).

Each of these factors is now considered in turn.

Damper installation

63 It is possible that a damper pad that was already close to the wear limit was installed at the last VIBT examination.

64 The last VIBT examination on wagon 10769 was carried out at Freightliner's facilities at Dunbar Cement Works on 29 January 2014. It was reported to the RAIB that as part of this examination, the wagon was lifted so the wheelsets could be removed and all of the suspension components examined and measured in accordance with Freightliner's vehicle maintenance instruction.

65 The documentation for this examination shows that all of the damper pads at the end of the examination were recorded with a length of 69 mm. This suggests that the damper pad in each corner had been replaced with a new one. There was no requirement for staff to record the length of damper pads they removed.

66 Freightliner reviewed how the suspension examination was carried out at Dunbar and identified it was possible that a partly worn damper pad could have been installed in the leading right-hand corner during the examination. Data for amounts of damper pad wear (paragraph 55) indicates that there is usually only between 1 and 2 mm of wear between annual examinations. Therefore if a damper pad that was worn close to the wear limit of 65 mm had been placed in this corner, the small amount of remaining hardened material could have worn away leading to a significant amount of wear as found. This possibility cannot be discounted.

Wheelset alignment

67 **It is probable that a problem with the alignment of the leading wheelset within its suspension caused excessive damper pad wear while also increasing the propensity of the wagon to derail.**

68 The marks on the wear faces of the damper pad (figure 13) indicate that it had been rotating while in service (paragraph 61). Normally, the larger diameter face of the damper pad will be sitting square against the friction liner plate on the saddle and move up and down against it. If the damper pad is not square against the saddle friction liner plate, the up and down movement will act on just one side of the wear face causing the damper pad to rotate (figure 14). The damper pad sits in a round bush in the pedestal and there is nothing to prevent it from rotating.

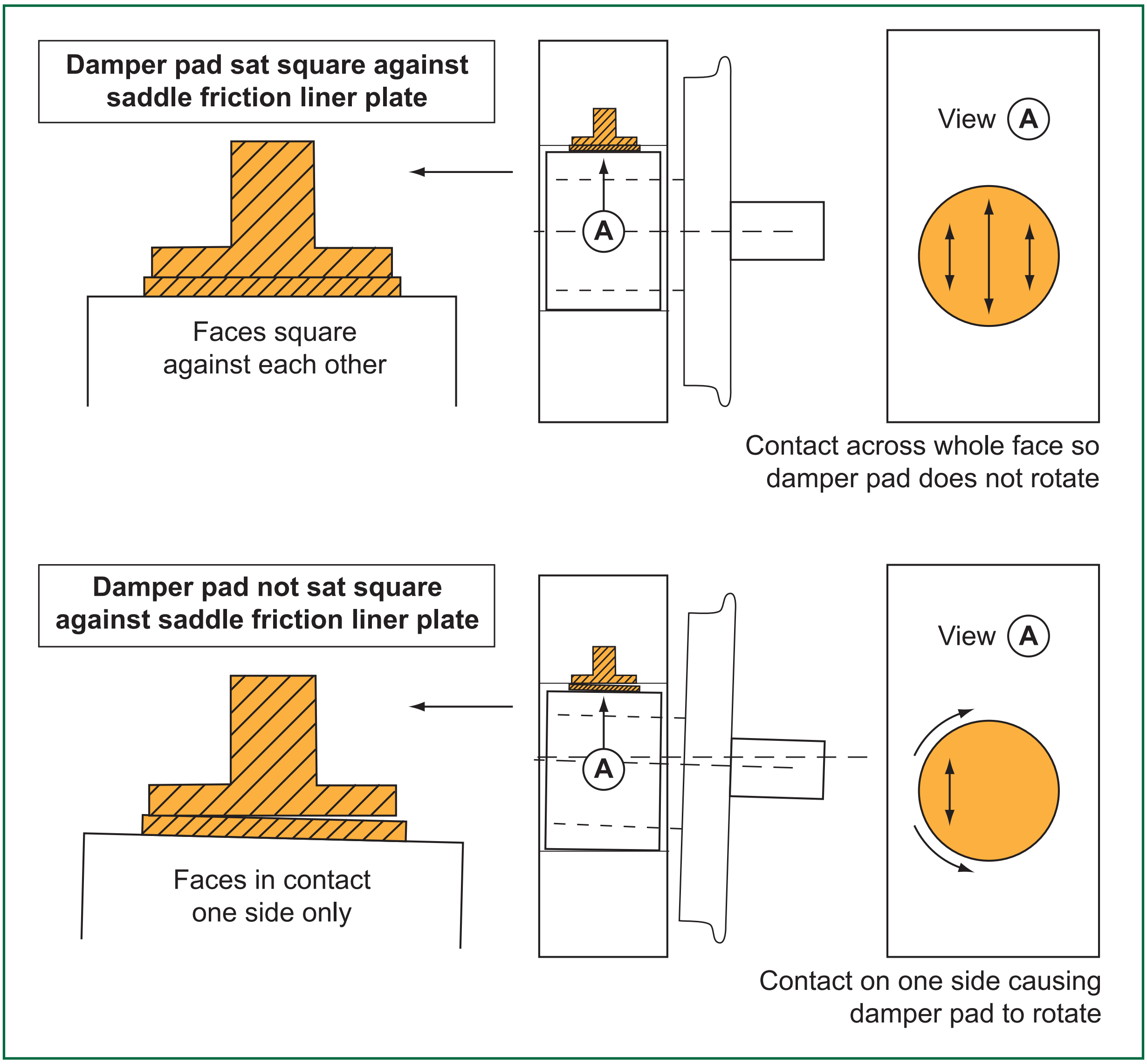


Figure 14: Mechanism for damper pad rotation within the suspension

69 The maintenance manual for the 'Mark 2' Gloucester pedestal suspension defines tolerances for the positions of the pedestals when bolted to the wagon's underframe. These dimensions are shown in figure 15. They are not normally measured; they would only be measured when the wagon was manufactured or if a pedestal on one corner was replaced.

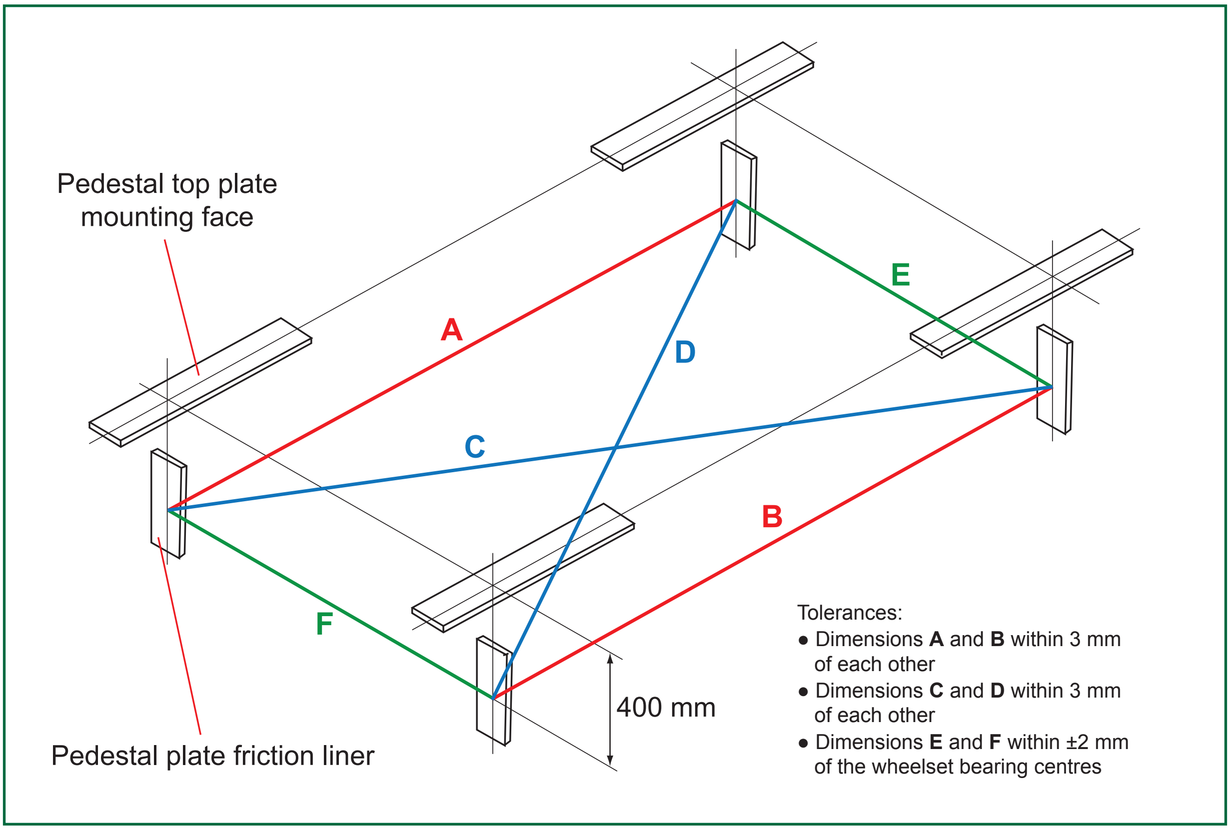


Figure 15: Tolerances for the positions of the pedestals (extracted from the maintenance manual for the 'Mark 2' Gloucester pedestal suspension)

70 The RAIB surveyed wagon 10769 after the accident to measure these dimensions and found the results did not fall within the defined tolerances[2]. This was probably due to the amount of damage that the pedestals had sustained while the wagon ran derailed. The trailing right-hand pedestal was the most damaged (figure 16). Further measurements taken at the top of the pedestal friction liner plates, where there was less damage to the pedestals, showed dimensions A and B and dimensions C and D (figure 15) were within about 1 mm of each other, which is within the specified tolerance. The measurement for dimension E (leading end) was in tolerance at 1.9 mm but dimension F (trailing end) was outside the tolerance at 3.8 mm.

71 The alignment of the leading and trailing pedestals was plotted using the measurements taken at the top of the pedestal friction liner plates. The results are shown in figure 17. The measurements for the trailing pedestals indicate that the left-hand pedestal is perpendicular to the wagon's frame but the right-hand pedestal turns inwards. However, this pedestal was damaged in the accident (figure 16). The measurements for the leading pedestals indicate both pedestals turn a very small amount inwards towards each other. If the wheelset was running aligned with the left-hand side pedestal, the saddle would not be squarely aligned within the pedestal on the right-hand side. As discussed earlier (paragraph 68), this would allow the damper pad to rotate and cause its spigot end to wear away.

[2] Dimension A-B was measured as 9 mm (tolerance is 3 mm), dimension C-D was 7 mm (tolerance is 3 mm) and dimension E for the leading wheelset position was 3mm (tolerance is ±2 mm).

Figure 16: The damage to the trailing right-hand pedestal

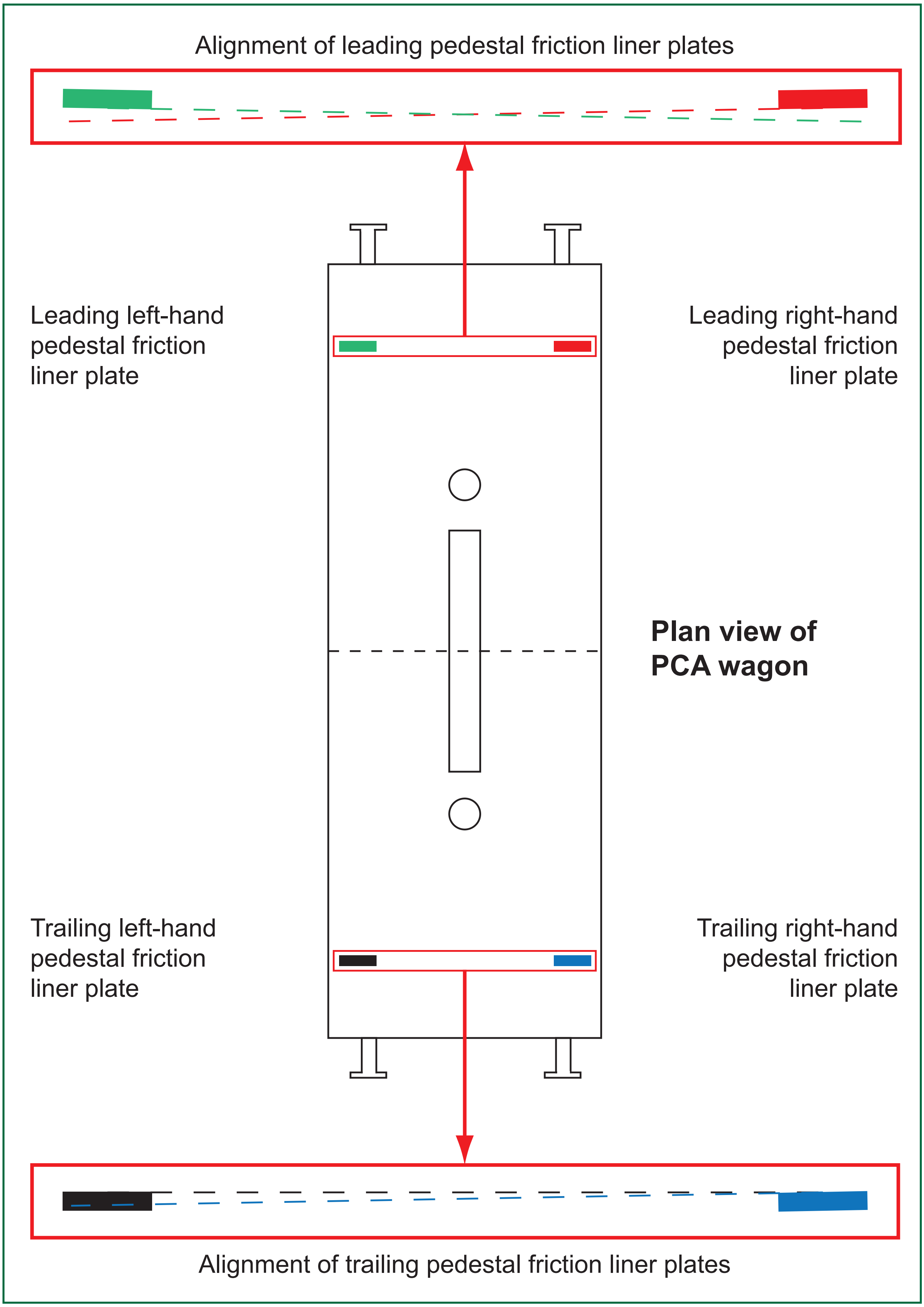


Figure 17: Leading and trailing wheelset alignment

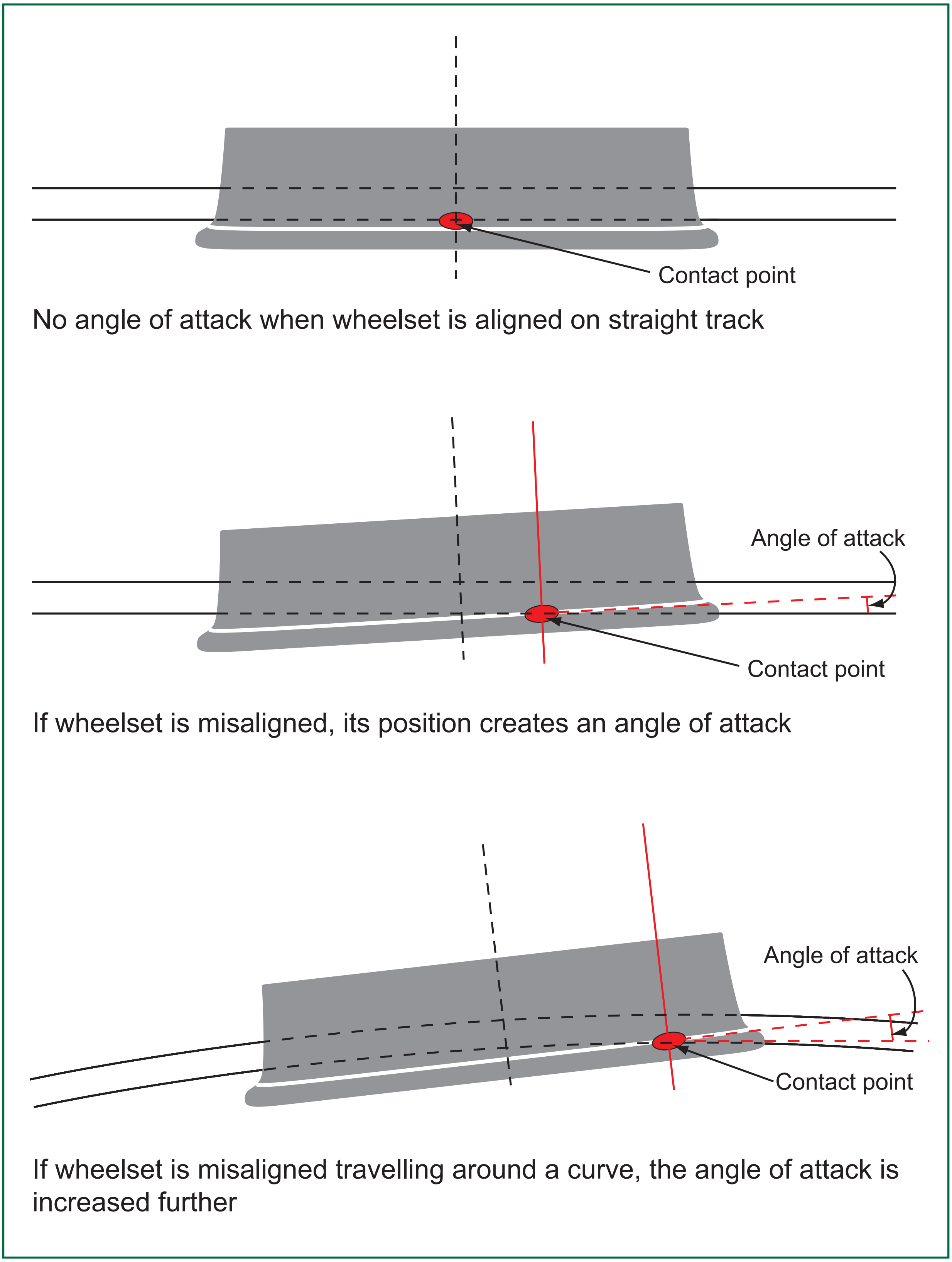


Figure 18: Wheelset angle of attack

72 It is probable that the alignment of the leading wheelset in its pedestals on wagon 10769 caused the excessive wear to the damper pad found on the leading right-hand corner. However, this small amount of misalignment was not enough to cause the wheels to wear quickly or unusually. Maintenance records showed this wheelset was placed under wagon 10769 in October 2012 and wheel profile measurements taken after the derailment did not show high levels of wear or any unusual tread or flange wear.

73 If the leading wheelset was misaligned within the suspension, this would alter its position while running. This would become more significant while travelling around a curve because it would increase the wheelset's angle of attack; this is the angle between the running edge of the rail and the plane of the wheel flange (figure 18). Changing the wheelset's angle of attack alters the amount of lateral force where the wheel is in contact with the rail, which could give rise to the conditions required for a derailment as indicated by the vehicle dynamics study (appendix D, paragraph D6).

Condition of the track

74 **The ballast on the approach to the point of derailment on the Down Sunderland line was heavily contaminated with slurry, resulting in wet beds and vertical track geometry faults that required maintenance action, including a cyclic top defect which should have resulted in the imposition of an emergency speed restriction.**

75 Figure 19 illustrates how much the ballast on the approach to the point of derailment was contaminated. The wet beds extended over a distance of about 13 metres (18 sleeper bays) and variations in the height of the rails could be seen by eye (figure 20).

76 Track geometry recording trains had measured these variations in the vertical track geometry. Track geometry data is plotted on a trace and the trace from the last run prior to the derailment (paragraph 37) shows the variations in the level (or top) of the left-hand and right-hand rails (figure 21). The trace for the right-hand rail shows three changes in top in short succession exceeding the intervention limit for track maintenance in NR/L2/TRK/001/mod11[3]. The trace shows that the differences in level between the two rails were not enough to cause a *track twist* that required maintenance action. It also shows rates of change in the height of the rails were large enough for dip angles to be recorded. Dip angles are normally observed at joints or welds in the track rather than on sections of continuously welded rail.

77 The dips in the right-hand rail were regular and of sufficient amplitude for the track geometry fault report from this recording to include cyclic top defects (appendix E, paragraphs E1 to E2). One cyclic top defect was a category A fault with a wavelength of 18 metres. NR/L2/TRK/001/mod11 required a 30 mph (48 km/h) emergency speed restriction to be imposed within 36 hours and maintenance action to correct it within 14 days.

[3] For track geometry recorded as part of the track inspection regime, NR/L2/TRK/001/mod11 requires these three faults, known as top defects, to be repaired within 14 days. However, as these faults were recorded by a PLPR train, the TME1 had agreed that the track maintenance team did not have to respond to these faults within this timescale (paragraph 156).

Figure 19: The ballast and wet beds on the approach to the point of derailment (image courtesy of Network Rail)

Figure 20: The variation in the height of the rails on the approach to the point of derailment (image courtesy of Network Rail)

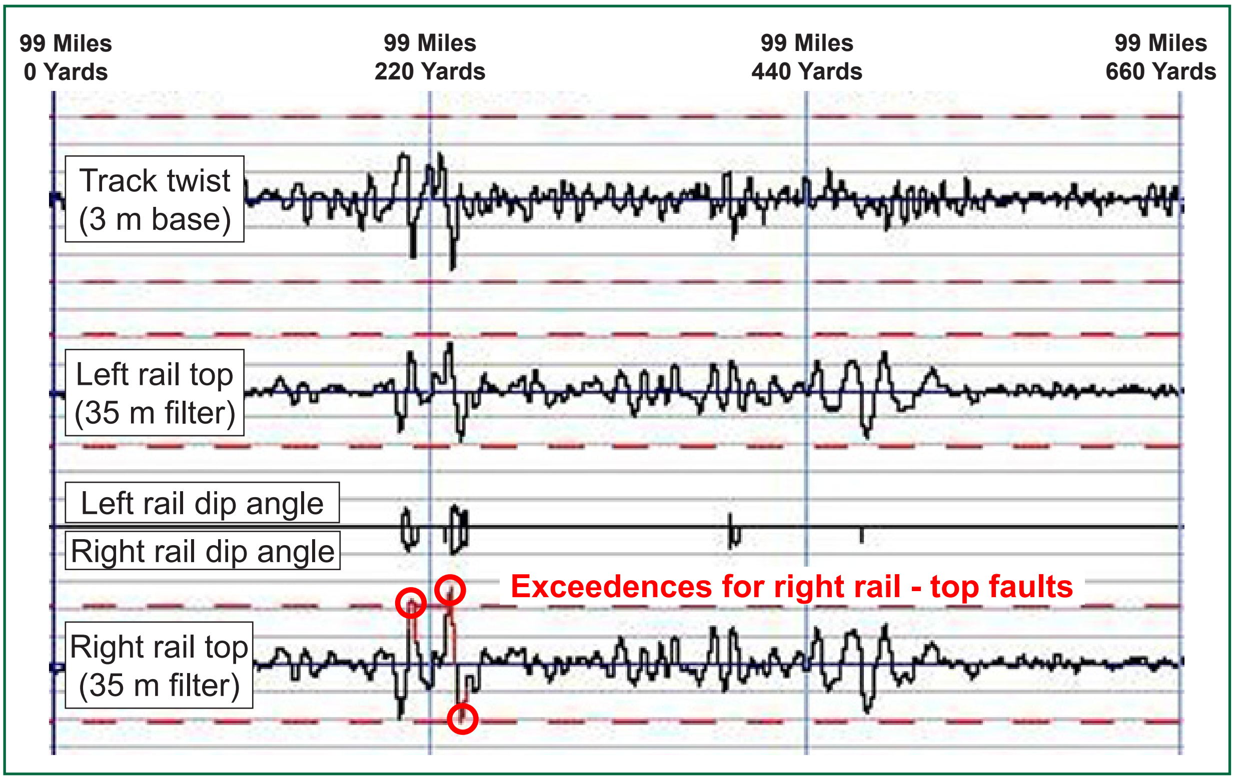


Figure 21: Extract from the track geometry trace recorded on 11 October 2014

No emergency speed restriction

78 **A 30 mph (48 km/h) emergency speed restriction was not applied for a cyclic top defect on the Down Sunderland line at Heworth, which allowed train 6S26 to pass over the cyclic top at up to its maximum speed of 60 mph (97 km/h).**

79 While the permissible speed on the Down Sunderland line at Heworth is 70 mph (113 km/h), train 6S26 was a class 6 freight train which was permitted to travel at speeds of up to 60 mph (97 km/h). Train 6S26 was travelling at 51 mph (82 km/h) when it derailed.

80 The PLPR train that ran over the Down Sunderland line on Saturday 11 October 2014 reported a category A cyclic top defect (paragraph 77). This defect fell into a category that meant it was passed on to the local on-call maintenance team (paragraph 156) so it could either repair the fault or impose a 30 mph (48 km/h) emergency speed restriction.

81 The on call maintenance team that started its night shift on Sunday 12 October was tasked with repairing the cyclic top defect. The team went to the site that evening, during darkness. The team leader found the cyclic top defect noting that the dips in the rails were due to a significant number of wet beds and severely contaminated ballast. After assessing the track, the team leader spoke to TSM1 and explained that he could not repair the defect because he did not have enough workers or the required tools with him, and it was difficult to repair vertical track geometry faults in darkness. The team leader suggested that a 30 mph (48 km/h) speed restriction was put on it. TSM1 asked the team leader to do what he could and TSM1 indicated that he would visit the site the next day to assess if a 30 mph (48 km/h) speed restriction was required.

82 There was no further communication between TSM1 and the team leader. The team leader did not carry out any repair work, but the following morning TSM1 closed the fault as he believed that a repair had been carried out. Consequently, a 30 mph (48 km/h) emergency speed restriction was not imposed despite the presence of the cyclic top defect.

83 If this 30 mph (48 km/h) speed restriction had been in place, the dynamic modelling (appendix D, paragraph D8) predicts there would not have been any risk of the wagon derailing, even with a loss of damping within its suspension.

Cyclic top defect

84 The cyclic top defect and associated vertical track geometry faults arose due to a combination of the following:

a. Water was present in and under the track bed (paragraph 85).

b. The wet beds and resulting vertical track geometry faults at Heworth were repeatedly found by the track inspection regime, but other than mandated reactive repairs in response to fault reports from track geometry recording trains, no repairs were planned or took place (paragraph 97).

c. The limited amount of reactive repair work that took place at Heworth was done to sign off reported track geometry faults, which had to be completed within a short timescale, but these repairs were ineffective (paragraph 113).

d. The track at Heworth had not been renewed in 2013 as intended and the mitigations identified following this track renewal shortfall were not carried out (paragraph 119).

Each of these factors is now considered in turn.

Water in and under the track

85 **Water was present in and under the track bed.**

86 The point of derailment is in a small cutting and on a falling gradient (in the direction of travel) on the Down Sunderland line, starting at Pelaw at 98 miles 484 yards. These features channel water towards and under the railway lines. Track drainage is installed in the *six foot* between the Up and Down Sunderland lines to take this water away.

87 Network Rail's Route Asset Manager (track) (the RAM (track))[4] was allocated budget for track drainage improvements on LNE Route and the Track Maintenance Engineers were asked to propose locations where such improvements could be made. The Heworth station area was one of the proposed locations.

88 Network Rail's Works Delivery organisation was used to deliver this work and during 2013 it planned to make drainage improvements at Heworth. The scope of work proposed by Works Delivery is shown in figure 22.

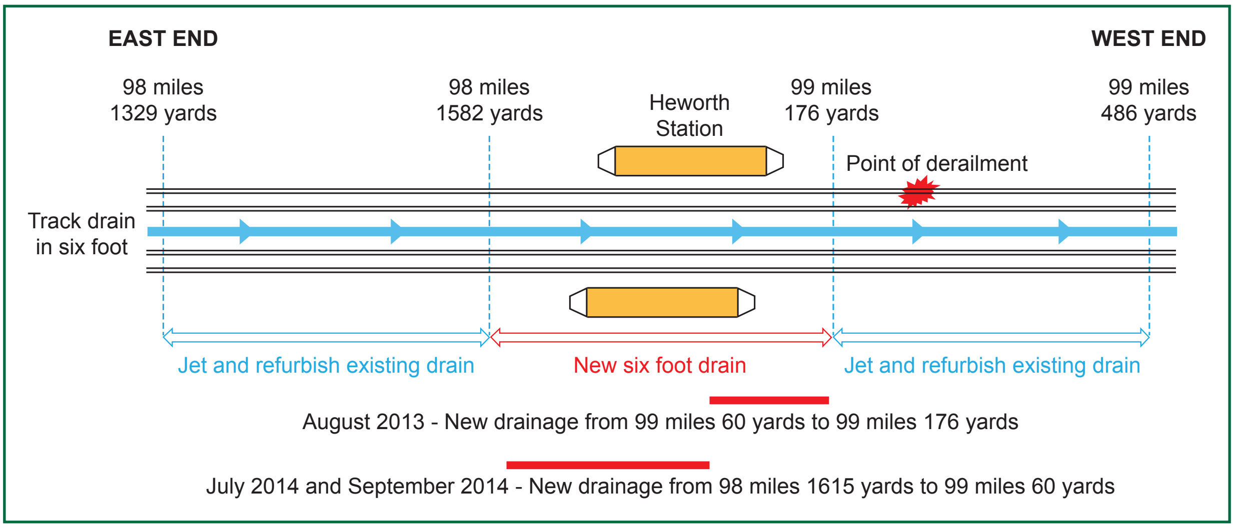


Figure 22: The scope of the proposed track drainage improvements at Heworth

89 Works Delivery began work at Heworth in August 2013 with the installation of a new track drain in the six foot through the station, from 99 miles 60 yards to 99 miles 176 yards. The outfall from this new track drain fed into the existing track drainage at the west end of the station. Shortly afterwards, the RAM (track) halted this work as he had not been consulted about where Works Delivery had chosen to make the drainage improvements. Additionally Works Delivery had not submitted a design for the new drainage to his team for approval.

[4] The RAM (track) is a senior manager who is responsible for managing the condition of the track assets on a Route by setting targets for volumes of maintenance work to be delivered and controlling the budget for the track renewals programme. The team working for the RAM (track) monitor the outputs of this work using track quality indicators. The RAM (track) team is independent of the track maintenance organisation but provides support to it and checks that it is correctly applying the relevant standards for track assets.

90 Works Delivery submitted the track drainage design to the team who work for the RAM (track) for review and approval in June 2014. During this review, the RAM (track) team noted from the drainage survey that there was a problem with the drainage invert levels for the existing drainage at the west end of the station. The gradients for the pipes between the drainage catch pits were uneven, with some too shallow and others too steep. The reviewer was also aware that there had been a rough ride reported just to the west of Heworth station earlier in 2014, which he took to be an indication that the existing drainage was not functioning correctly. As a result, the RAM (track) team decided to amend the design by extending the provision of new drainage from 99 miles 176 yards further to the west as far as 99 miles 319 yards. They expected that this would correct the problem with the existing drainage found by the survey.

91 Work to the approved design recommenced and Works Delivery carried out six shifts between the end of July and mid-September 2014. This work installed new track drainage from 99 miles 60 yards to 98 miles 1615 yards, continuing to the east through Heworth station towards Pelaw. Works Delivery and the RAM (track) team had agreed that the new drainage would be installed first, then the existing drains would be jetted and refurbished as required. By installing the new drainage first, with its outfall into the existing track drainage, they believed this would help to prove if the existing drainage to the west of Heworth was working. Those parts that were not working could then be identified and refurbished.

92 By the time of the accident the existing track drainage on the approach to the point of derailment had not been refurbished or jetted, and no work had taken place to renew this drainage after the problem had been found with its invert levels. However, since August 2013, water collected by the newly installed track drainage had been flowing into the existing drainage, further concentrating water in the area around the derailment site.

93 While functioning track drainage will take water away from under the track, the ballast also needs to be free draining so that water can flow through the track bed and down to the drain. At Heworth, the ballast on the approach to the derailment was severely contaminated (figure 19) which prevented water from draining out of the track bed. One sign of water being held in the track bed was vegetation growing in the four foot of the Down Sunderland line during 2014 that could be seen on the footage from track geometry recording trains (figure 23).

94 In 2006, the then Track Maintenance Engineer proposed that the track in the Pelaw to Heworth area should be renewed, citing ballast contamination as the key reason. Documentation for the proposed renewal noted that the installed ballast dated back to 1972 and over many years the ballast on the Down Sunderland had become contaminated by coal dust. In 2011 when this renewal work was scoped, it included Network Rail digging trial pits at various locations along the Down Sunderland line. A trial pit was dug at 99 miles 220 yards, which is close to the point of derailment, and found that from the surface of the ballast to a depth of 400 mm, the ballast was heavily contaminated with coal dust and silt. From 400 mm to 650 mm down, the ballast was noted as heavily contaminated with clay and silt. Standing water was found at 650 mm below the surface. Track renewals subsequently took place in the Pelaw to Heworth area in 2012 and 2013 but this work did not include the point of derailment (see paragraphs 120 to 125).

Figure 23: Footage recorded in May 2014 showing vegetation growing in the four foot of the Down Sunderland line (image courtesy of Network Rail)

95 Ballast can also become worn and rounded over time due to the pieces rubbing against each other when a train passes. Ballast will rub and wear against the bottom of the concrete sleepers sitting on top of it. This rubbing action creates small pieces of ballast, like sand, and concrete dust, which collectively are referred to as 'fines'. When these fines and the coal dust combine with water that has not drained out of the track bed, they stick together and solidify to create a slurry and a wet bed forms. The action of passing trains pumps the slurry up to the surface where it covers the sleepers, track fastenings and foot of the rail (figure 24).

96 Once wet beds have formed, they further hinder track drainage and over time the number of wet beds will increase (see figure 25). During dry weather when the wet beds dry out, the slurry solidifies within the ballast to form a very hard material which is very difficult for maintenance staff to dig out by hand.

No planned repairs

97 **The wet beds and resulting vertical track geometry faults at Heworth were repeatedly found by the track inspection regime, but other than mandated reactive repairs in response to faults reports from track geometry recording trains, no repairs were planned or took place.**

98 Wet beds often coincide with dips in the rails due to voiding under the sleepers. Individual dips result in discrete top defects. As trains continue to run over the wet beds and their number increases, the number of dips will also increase resulting in cyclic top defects.

Figure 24: Close up view of a wet bed at the point of derailment on the Down Sunderland line (image courtesy of Network Rail)

99 Fault reports and data from track geometry recording trains that ran over the Down Sunderland line show that the top defects were first recorded at the point of derailment in 2012. During 2013, no track geometry faults were reported but wet beds could be seen. During 2014, track geometry recording trains had regularly been reporting vertical track geometry faults at this location. Left-hand and right-hand rail top defects requiring action within 14 days were reported on 1 February. A right-hand top defect, requiring action within 14 days, was reported on 2 May. On 2 August, a track geometry recording run reported a right-hand rail top defect that needed to be repaired within 14 days. This run also reported a category D cyclic top defect that required maintenance action within 60 days to correct it.

100 Network Rail's track geometry recording trains are also fitted with forward facing cameras. Footage from runs dating back to 2012 shows how the ballast contamination and number of wet beds grew over time (figure 25). The data and footage from track geometry recording trains was showing that the track at the point of derailment was deteriorating, and the amount of contaminated ballast was increasing.

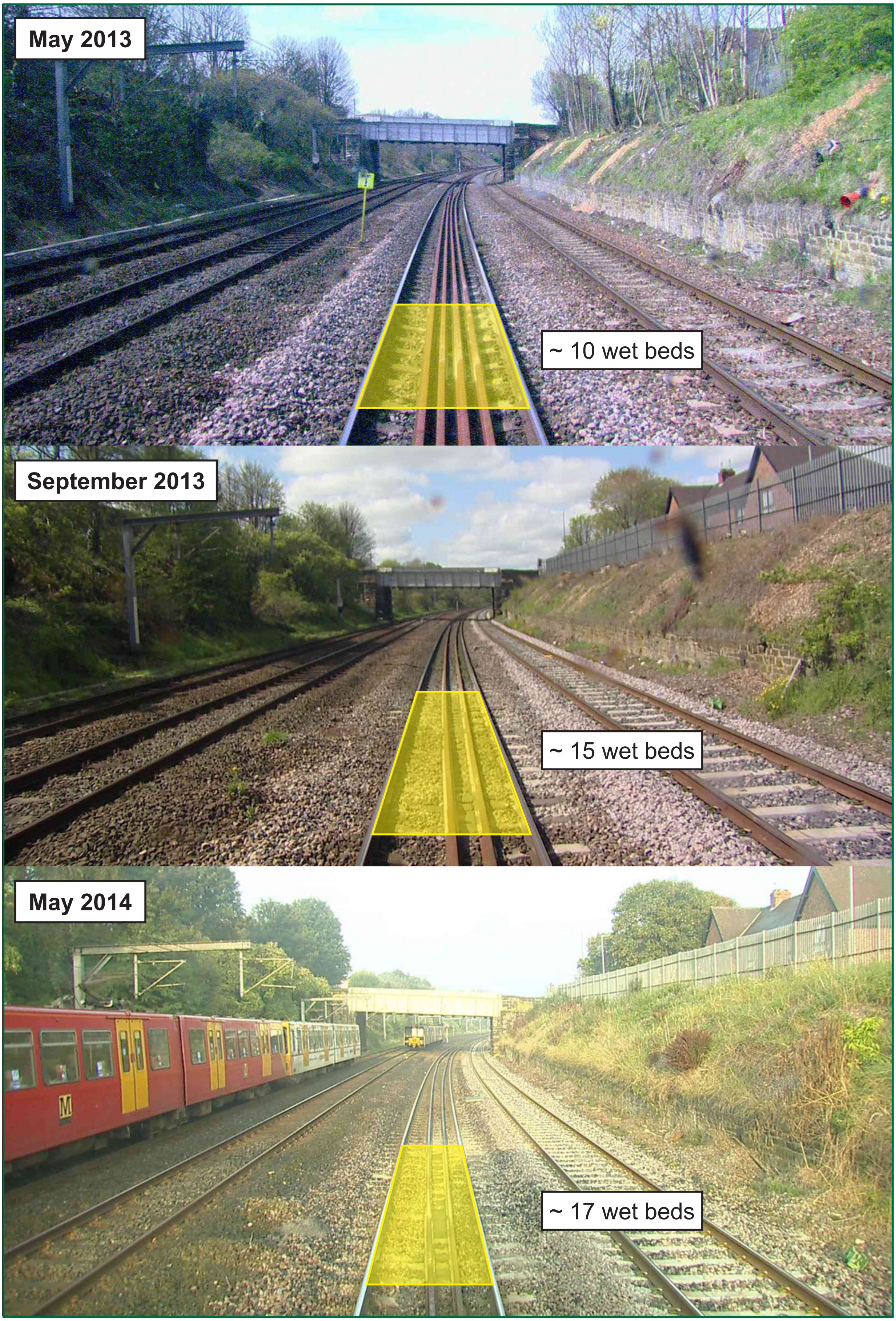


Figure 25: Footage showing increasing numbers of wet beds over time (images courtesy of Network Rail)

101 The track geometry recording trains that ran over the Down Sunderland line also recorded a *standard deviation* (SD) value for the overall quality of the vertical track geometry for each eighth of a mile section (appendix E, paragraphs E3 to E4). A chart showing how the SD values for the eighth of a mile section in which the train derailed have changed over the previous 10 recordings is shown in figure 26. It shows that the SD value for the portion of track from 99 miles 220 yards to 99 miles 440 yards had worsened over that time, falling into the very poor band in August 2013. In 2014, each run recorded a SD value which fell in the *super-red* band (appendix E, paragraph E4).

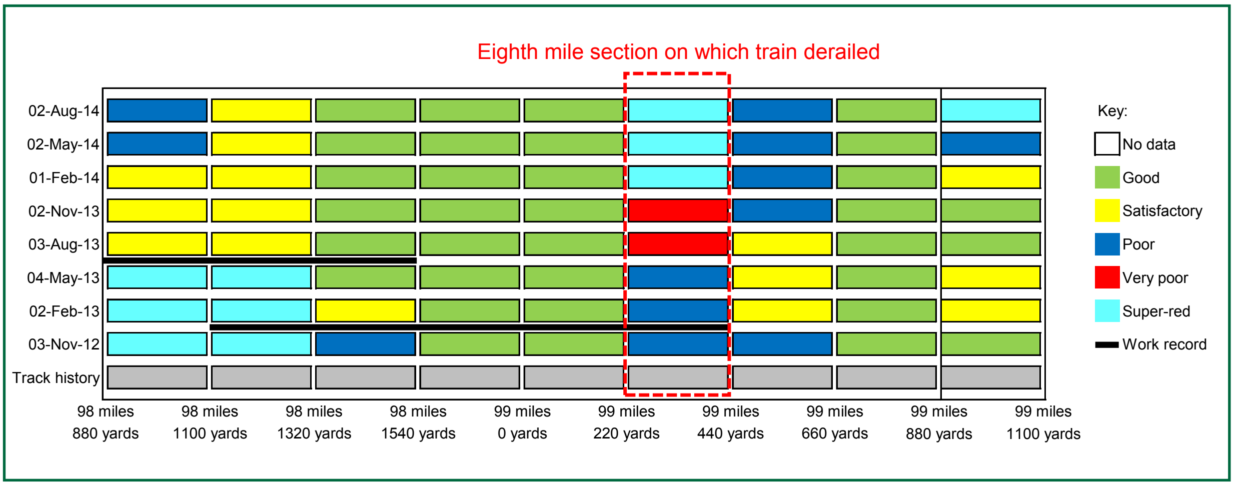


Figure 26: Chart showing the SD values recorded on the Down Sunderland line

102 When the SD value fell into the very poor band, NR/L2/TRK/001/mod11 required TSM2 to inspect this track by no later than the next supervisor inspection. The aim of this inspection is to identify the actions needed to address the underlying causes of the very poor track geometry, improve the condition of the track components and rectify track geometry defects. However, there is no evidence that this inspection took place.

103 When the SD value fell into the super-red band, NR/L2/TRK/001/mod11 required TSM2 to inspect this track within 14 days. The aim of this inspection is to identify what remedial work is needed to move the SD value out of the super-red band, or mitigate the super-red SD value by imposing a speed restriction (the speed is reduced in accordance with a table in NR/L2/TRK/001/mod11 so that the recorded SD value no longer falls in the super-red band). However, there is no evidence that this inspection took place when the SD value was first recorded in the super-red band in February 2014 or again three months later in May.

104 The Track Maintenance Engineer also reviewed the output from each track recording train to identify any additional track maintenance work that he wanted to be done:

- May 2013 – TME2 noted that the vertical track geometry was deteriorating and called for the track to be lifted and packed within 3 months.
- November 2013 – TME1 noted the SD value for 99 miles 220 yards to 99 miles 440 yards had fallen into the very poor band and called for TSM2 to inspect the track. He also noted that he needed to propose a track renewal over this mileage.

- February 2014 – TME1 noted the SD value had fallen into the super-red band, with large left and right-hand rail top defects being reported, and so he asked TSM2 to inspect the track.
- June 2014 – TME1 called for the track to be tamped from 98 miles 1540 yards to 99 miles 1100 yards (which included the point of derailment).
- August 2014 – TME1 noted the wet beds in the Heworth area and set an action for them to be removed followed by the use of a *stoneblower* to correct the track geometry within 4 months.

105 During 2014 other parts of the track inspection regime were also reporting the wet beds and deteriorating vertical track geometry:

- 12 January – the wet beds were noted during a cab ride inspection by TME1 and given a priority of 3 months for removal.
- 2 May – a basic visual inspection reported poor top due to the wet beds. A priority of 6 months was set for digging out the wet beds.
- 30 June – a basic visual inspection reported there were wet beds and cyclic top was now forming. The patroller recommended a priority of 2 months for removal.
- 16 July – TME1 noted a poor ride over this track during a cab ride inspection which he noted was due to the wet beds and set a priority of 5 months for them to be dug out.
- 5 August – a Supervisor inspection reported the wet beds and called for them to be dug out mechanically within 6 months. The inspection also noted that cyclic top was forming and that the track needed to be tamped within 6 months.
- August (date not recorded) – TMS2 carried out an inspection due to the SD value for this eighth of a mile section of track being in the super-red band for vertical track geometry. This noted the poor ballast condition and wet beds at the site. He recommended a remedial action to lift and pack the wet beds within 3 months. The recommended action for a permanent repair was to remove the wet beds, re-ballast the track and then tamp it. A priority of 6 months was set for this.

106 The RAIB could not find any records for supervisor cab ride inspections over the Down Sunderland line. Network Rail's system for managing the inspection and maintenance of its track assets, known as Ellipse, recorded that these inspections had taken place as required but the findings from them were not documented. The RAIB was also unable to find any documented record for the last Track Maintenance Engineer inspection which took place in July 2013, which was about the time the Track Maintenance Engineer changed. This inspection was delegated by TME2 to a supervisor who had the knowledge and skills to do it, although they did not have the formal delegated authority to do it. While this inspection is shown on Ellipse as complete, its findings are unknown.

107 In addition to the track inspection regime, the RAM (track) team, TME1 and TSM2 carried out a number of office based reviews to look at the condition of track assets. These reviews looked at each eighth of a mile section of track in turn, using track geometry data and footage from trains to identify and understand the issues, and then decide on the actions needed. These actions could range from manual repair work, to tamping or stoneblowing with *on-track machines*, through to proposing a track renewal. If necessary, a site visit could be planned to better understand the problem or actions needed. These reviews started in February 2014 and were initiated by the RAM (track) to identify proactive work that could be done to reduce the high number of track geometry issues in the Newcastle Track Maintenance Engineer's area (both discrete faults and SD values in the super-red band). When the Down Sunderland line at Heworth was reviewed, the meeting attendees identified that wet beds were an issue and recorded an action to remove them and use a stoneblower to correct the track geometry. The action was given a priority that required it to be completed within four months.

108 During 2014 there were two reports from train drivers that their train had ridden poorly over the Down Sunderland line just after Heworth station. These are referred to as rough ride reports and are another indication of poor track geometry. The first rough ride report was in February when a driver reported a problem just after Heworth station at some wet beds. The second was in July when a driver reported a rough ride in the same place. On both occasions track maintenance staff responded and carried out repairs by lifting and packing the track. Trains were then allowed to travel over this track at the line's permitted speed. Network Rail's standards require a form to be filled in which records the condition of the track when the repair is complete and what checks have been completed before trains can run at line speed. It was common practice for these forms not to be filled in and no evidence could be found that these checks took place.

109 Each time a problem was reported at Heworth, an action to repair the track was called for, along with a suggested timescale for doing it. However, the RAIB found no corresponding records on Ellipse, so none of the reported faults were recorded in Network Rail's system for planning and managing the repairs through to completion. Consequently there was no evidence that any repair work was formally planned or carried out.

110 Data on Ellipse showed that work orders to plan and carry out repairs were being raised up until the start of 2014. In January, TSM2 was absent from work for two months due to illness and, shortly afterwards in February, the Section Administrator left to go on maternity leave and was not replaced until after the derailment. One of TSM2's tasks was to review the output from the track inspection regime, agree what work was needed and set a timescale. The Section Administrator should then create work orders on Ellipse, including what needs to be done, where and by when. With neither of these post holders at work, paperwork from the track inspection regime was left on a desk and no work orders were created on Ellipse. Occasionally the Section Planner created work orders on Ellipse so that work could be planned but she was too overloaded to do any more than that. Over time, the information on Ellipse became more and more out of date and did not reflect the work needed to maintain the track assets in TSM2's area.

111 The only evidence of repair work taking place at Heworth was in response to rough ride reports (paragraph 108) and the mandated deadlines for repairing track geometry faults found by track geometry recording trains (see paragraph 113). Often these reactive repairs were not recorded on Ellipse and the only evidence that they had taken place were signed off copies of the sheets listing the track geometry faults reported by each track geometry recording run.

112 The RAIB found that sometimes even the faults reported by track geometry recording trains were not repaired. The track geometry recording run on 2 August 2014 reported a top defect that required repair within 14 days, ie by 16 August. On 26 August, track maintenance staff went to Heworth to repair this fault. In the meantime, the RAM (track) did not receive a request for a dispensation for exceeding the mandated repair timescale. The Team Leader who attended, assessed the condition of the track and decided that the ballast condition was too bad to effect a repair, as any work they did could worsen the track geometry. He reported this to TSM1 who asked him to 'give it a tickle'. This is a term used locally that describes doing some lifting and packing of the track to allow a fault to be signed off. The Team Leader on site decided against doing this, so instead he made a note, on the sheet listing the faults, that there were wet beds. However, he did not sign it off. On 11 September the top defect was signed off by a supervisor who manages the track geometry fault sheets. He knew the other Team Leader had been to the site and assumed that a repair had taken place so signed the fault off. However, no repair work had taken place.

Reactive repairs

113 **The limited amount of reactive repair work that took place at Heworth was done to sign off reported track geometry faults, which had to be completed within a short timescale, but these repairs were ineffective.**

114 The reactive repair work the track maintenance teams carried out at Heworth comprised manually lifting and packing the track over short distances, with estimated amounts of stone chippings or ballast placed under the track. More effective measured shovel packing repairs (appendix E, paragraph E5) were not carried out, primarily due to the time needed to do this. The aim of the repairs that took place was to lift out dips over small sections of track. However, this manual lifting and packing was ineffective due to the severity of the ballast contamination. The presence of unused rails lying in the four foot of the Down Sunderland line (figure 19) also hampered this type of work.

115 The track maintenance teams were manually lifting and packing the track just so that they could meet the timescales for signing off the faults found by track geometry recording runs. They knew that the repair work they had done would not last, and that to make an effective and longer lasting repair to the track at Heworth, the wet beds needed to be dug out and replaced with fresh ballast. In 2013 when there were a smaller number of wet beds, these could have been dug out manually by hand but no work took place to do this. By 2014 the number of wet beds had increased to the extent that they now needed to be dug out mechanically, using a *road rail vehicle* with a special bucket attachment. This type of work requires much more planning.

116 Network Rail planned a mechanical dig using a road rail vehicle during the week commencing 31 August 2014 in conjunction with other work taking place at St James Bridge junction. When the work at the junction was cancelled, the hire of the road rail vehicle was also cancelled so the wet bed removal work did not happen. Network Rail re-planned the wet bed removal work for the week commencing 19 October but this was subsequently cancelled as it clashed with work that Works Delivery were doing in the Heworth area. It was re-planned again but was not due to take place until after the derailment happened.

117 Data from track geometry recording trains confirmed that on many occasions, the manual reactive repairs carried out by the track maintenance teams were ineffective, as the same track geometry faults were recorded repeatedly. However, due to the high volume of track geometry faults that the track maintenance teams needed to attend to (see paragraph 129), each time they just did enough to allow the fault to be signed off in the limited time that they had. The track maintenance team then moved to the next fault on the sheet.

118 Witness evidence and track maintenance records show that the only work that the majority of the staff in the Newcastle track maintenance teams did was reactive work, in response to faults found by track geometry recording trains. The team leaders did not have a plan for what work was going to be done in any given week. Instead, they simply looked at the timescales for defects listed on the track geometry fault sheets for the Newcastle Track Section Manager area when deciding where they needed to go each day. Track maintenance staff said they rarely did any preventative maintenance work or longer lasting repairs such as digging out wet beds. Everything they did was driven by the mandated timescales for responding to track geometry faults.

Track renewal shortfall mitigation

119 **The track at Heworth had not been renewed in 2013 as intended and the mitigations identified following this track renewal shortfall were not carried out.**

120 The long term solution at Heworth required the track to be renewed. The need for replacing the ballast on the Down Sunderland line at Heworth due to contamination had first been identified back in 2006 (paragraph 94). In 2008 the RAM (track) team inspected the site, accepted this work needed to be done and expanded its scope to a plain line track renewal, ie replacing the ballast, sleepers and rails, as this was just as cost effective to do as replace the ballast. The track renewal was planned to take place through Heworth station (figure 27).

121 The RAM (track) team included the plain line renewal in the track renewals programme and initially proposed that it would take place during the financial year 2011/2012. Later in 2008, the RAM (track) team reprioritised it to take place in 2012/2013. This decision was reviewed in 2010 and the track renewal was brought forward again for delivery in 2011/2012. It was subsequently delivered by Network Rail Investment Projects in March 2012, with the track on the Down Sunderland line renewed from 98 miles 1560 yards to 99 miles 200 yards. This work stopped just short of where train 6S26 derailed at 99 miles 253 yards.

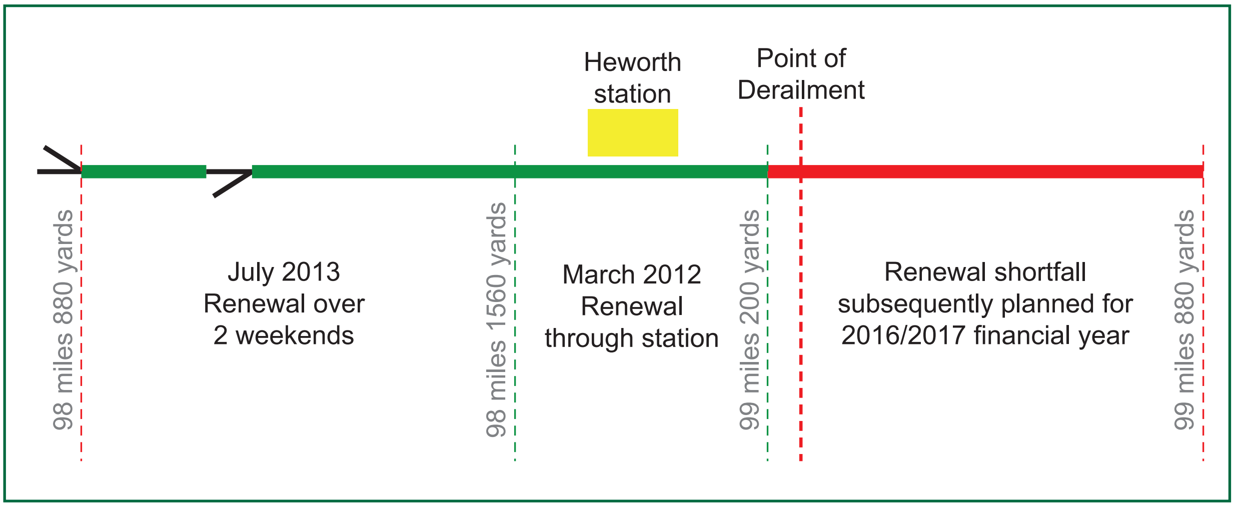


Figure 27: Track renewals on the Down Sunderland line

122 Due to ongoing issues with the track quality on the Down Sunderland line in the Heworth area, the RAM (track) team decided in 2012 to extend the track renewal mileage either side of the station so that it now covered from 98 miles 880 yards to 99 miles 880 yards (figure 27). The track from 98 miles 880 yards to 98 miles 1560 yards had a long standing 30 mph (48 km/h) speed restriction on it for poor top and cyclic top defects, which were due to contaminated ballast and wet beds. This part of the renewal was initially planned to take place in the financial year 2012/2013.

123 When the renewal was planned, Network Rail encountered problems in finding dates when it could take place. One difficulty arose as the work was taking place adjacent to the Tyne and Wear Metro lines. The operators of trains on Network Rail's infrastructure offered dates when these lines could be shut but many of these did not align with dates when the operator of the Tyne and Wear Metro trains was willing to close its lines. This significantly reduced the number of weekends in which the work could be done, and the times that the Tyne and Wear Metro infrastructure was scheduled to be closed were more restrictive than those Network Rail could accept for its own infrastructure. The number of available weekends for this renewal was further reduced by resource availability. Contractors' staff who were needed to deliver this renewal were already committed to other planned work on some of the weekends when access at Heworth was possible.

124 As a result of the problems in planning this renewal, Network Rail moved it into the 2013/2014 financial year. The limited number of weekends in which to do it meant the lower mileage end of the renewal was prioritised as this mileage had a long-standing 30 mph (48 km/h) speed restriction on it. The mileage to be renewed was agreed with TME2 and over one weekend in May and two weekends in July 2013 the plain line track between 98 miles 880 yards and 98 miles 1560 yards was renewed by Network Rail Investment Projects (figure 27). When the mileage to be renewed was agreed, the RAM (track) team spoke to TME2 about the section of track mileage that was not being renewed. At this time TME2 did not have any concerns about this track and did not ask the RAM (track) team to fund any additional work such as tamping or stoneblowing (appendix E, paragraph E8).

125 As Network Rail was unable to find any dates when it could renew the remaining track mileage, this resulted in a shortfall from 99 miles 200 yards to 99 miles 880 yards. When there is a renewal shortfall, Network Rail details the track mileage not delivered in a change control log. This is used to formally inform the RAM (track) team about the shortfall but only happens at the end of the work when a completion report is input onto the Track Renewal System (TRS)[5]. A completion report for this renewal was received by the RAM (track) team in December 2013. This triggered the RAM (track) team to create a shortfall renewal entry on TRS in January 2014 for the mileage not renewed (figure 27). This renewal was planned to take place during the financial year 2016/2017.

126 When the RAM (track) team received the completion report, it also triggered the need to complete a Risk Assessment for Deferred Renewal (RADR) form as required by Network Rail standard NR/L2/AMG/02201, 'Management of risk arising from Deferred Renewals'. The RADR form was completed in January 2014 and included a section that recorded the mitigation required for the deferred renewal which in this case was 'Isolated wet bed removal'. This section is completed to inform the Track Maintenance Engineer of what actions need to be taken to mitigate the risk from the shortfall.

127 The RAIB found no evidence that this mitigating action was being carried out by the track maintenance teams as they were spending all of their time carrying out reactive repairs for track geometry faults (paragraph 118). The track maintenance teams knew there were wet beds at Heworth but they were not removed (paragraphs 115 to 116).

Identification of underlying factors

Track maintenance workload

128 **The Newcastle Track Section Manager's team was unable to cope with the amount of track maintenance work it had to do.**

129 The track geometry recording trains running over the track assets in the whole of the area covered by the Newcastle Track Maintenance Engineer (figure 8) were consistently reporting a high number of track geometry defects. Figure 28 shows that over the past four years, this area has had the highest number of reportable track geometry defects on LNE Route. The number of track geometry defects was consistently much higher than the other LNE Track Maintenance Engineer areas.

130 Figure 29 shows that over the past four years the Newcastle Track Maintenance Engineer's area has had the highest percentage of eighth of a mile sections of track with a SD value in the super-red band on LNE Route. Again, the numbers for this Track Maintenance Engineer area were consistently higher than those for other LNE Track Maintenance Engineer areas.

[5] The Track Renewal System (TRS) is used by Network Rail to scope, plan and deliver its track renewals.

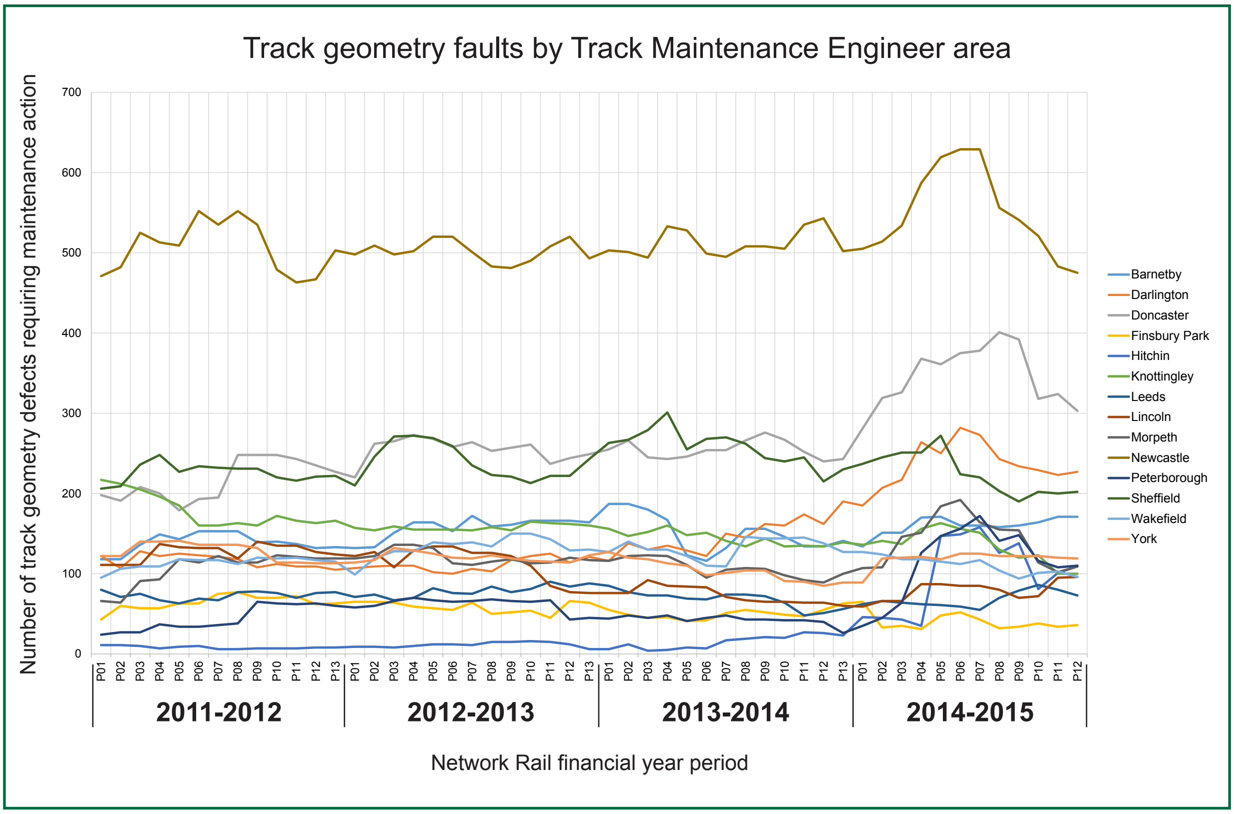


Figure 28: Numbers of reportable track geometry faults by Track Maintenance Engineer area on LNE Route

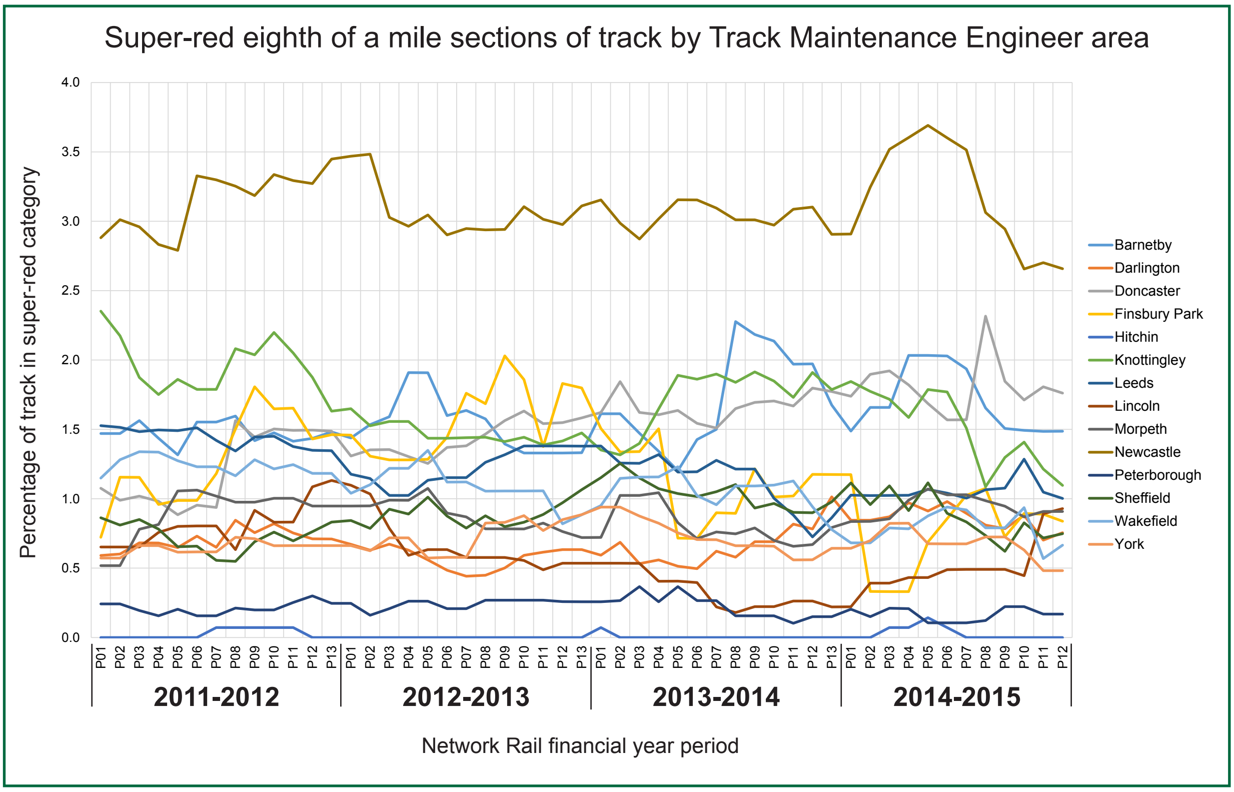


Figure 29: Percentage of eighth of a mile sections of track with a SD value in the super-red band by Track Maintenance Engineer area on LNE Route line

131 The Newcastle Track Maintenance Engineer area is the sixth largest of the fourteen Track Maintenance Engineer areas on LNE Route, in terms of its number of track miles. If the number of track geometry defects for each Track Maintenance Engineer area is normalised by using its number of track miles, the Newcastle Track Maintenance Engineer area has a consistently higher number of track geometry defects per mile than any of the other areas on LNE Route. Witness evidence indicated that while, in geographical terms, the Newcastle Track Maintenance Engineer area is not the largest, it is a difficult area to manage. In 2008 Network Rail had changed the Track Maintenance Engineer boundaries so the Newcastle Track Maintenance Engineer was responsible for the Newcastle and Middlesbrough Track Section Manager areas (paragraph 32). Witnesses explained that each of these areas has track assets which are challenging to maintain; the Middlesbrough area includes a lot of older track and points which are in a poor condition and generate a high number of track geometry faults, and the Newcastle area includes some old track assets plus others which are among the most complex on LNE Route, particularly in and around the Newcastle station area.

132 Network Rail's standards require track maintenance teams to respond to track geometry defects and repair them within a defined timescale. This requirement generated a high workload that the Newcastle Track Section Manager's team was unable to cope with. What repair work it did carry out with the number of staff and the time that it had was reactive, and was often ineffective (paragraphs 113 to 118). Therefore the numbers of track geometry defects continued to remain high, so there was very little time left for the track maintenance team to carry out any preventative track maintenance work. This was due to a combination of the following factors:

a. Reduced numbers of staff over a prolonged period affected the amount of preventative track maintenance that was carried out (paragraph 133).

b. Changes to the safe systems of work used for protecting staff carrying out track maintenance affected the amount of work that was carried out (paragraph 144).

c. Restrictions on gaining access to the track in the Heworth area affected the amount of track maintenance that was carried out at this location (paragraph 150).

d. Changes to track inspection increased the workload of the Newcastle Track Section Manager organisation (paragraph 153).

Each of these factors is now considered in turn.

Numbers of track maintenance staff

133 In April 2011 Network Rail reorganised its maintenance function; this reorganisation is referred to as 'phase 2b/c'. The phase 2b/c reorganisation implemented a standard maintenance organisation structure across all of its Routes. This resulted in each Track Section Manager area having a template organisation, although there were local variations within each Route due to differences in geography, the types of track asset and the ability to gain access to the assets. For phase 2b/c, Network Rail sized each Track Section Manager area by looking at factors such as the size of the existing maintenance organisation, the age and condition of the track assets in its area, and the volumes of track maintenance work being delivered.

134 The phase 2b/c template organisation for the Newcastle Track Section Manager organisation shows it had a total of 40 staff (figure 30). This comprised a Track Section Manager, 2 supervisors, a planner, a section administrator and 35 maintenance staff. Of these 35, 7 were allocated to track inspection and the remaining 28 to track maintenance. During 2014, the Newcastle Track Section Manager organisation had 2 vacancies in track inspection (ie 2 out of 7 posts were vacant) and 7 vacancies in track maintenance (ie 7 out of 28 posts were vacant).

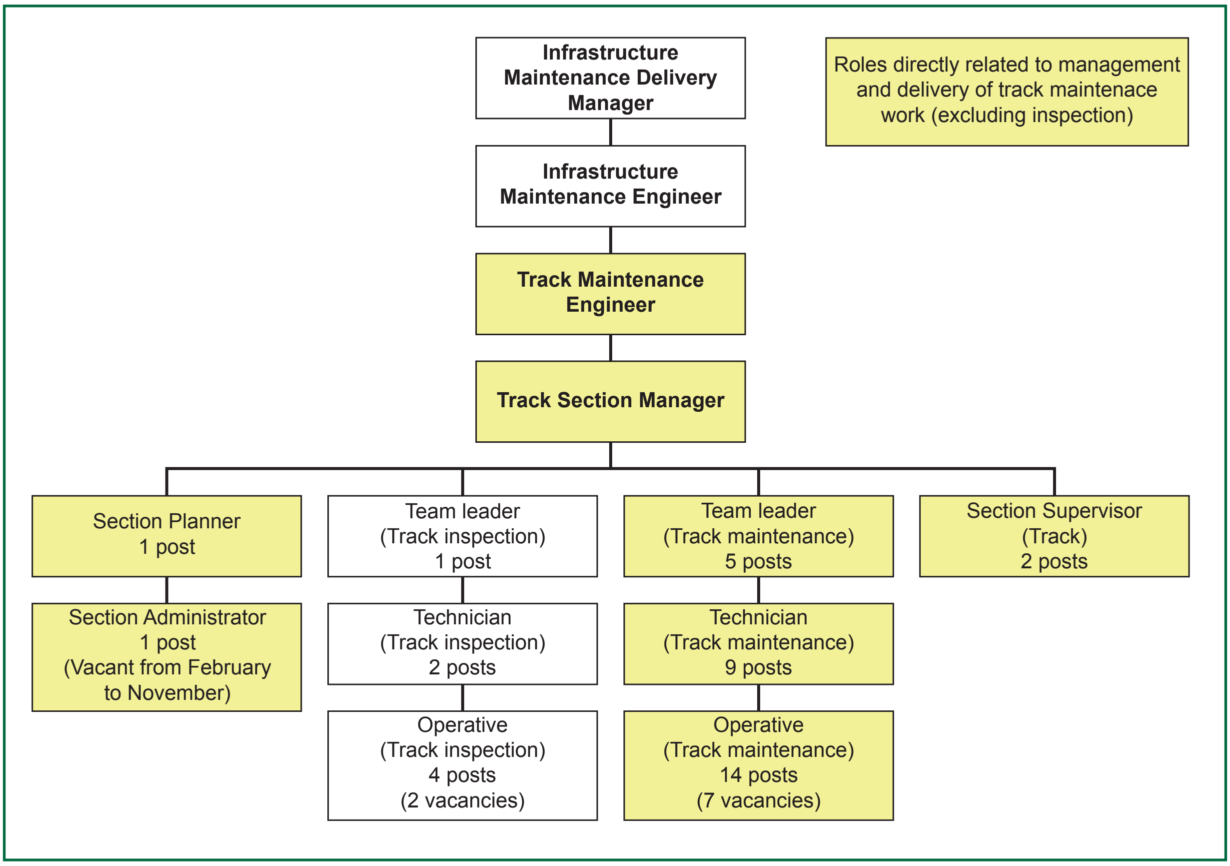


Figure 30: The Newcastle Track Section Manager organisation chart in 2014

135 The number of vacancies had increased since 2011 because posts had not been filled when staff had left. The Newcastle Infrastructure Maintenance Delivery Manager (IMDM) and the Newcastle Infrastructure Maintenance Engineer (IME) had been reluctant to recruit due to the introduction of PLPR (paragraphs 35 to 37) and the possible need to find roles for staff displaced from the track inspection team. However, since 2011 the timescale for introducing PLPR had been put back several times, which in turn had delayed any plans for recruiting staff. In addition to this, as work to introduce PLPR progressed, Network Rail reduced its estimates of how many staff would be displaced from inspection duties. By the start of 2015, Network Rail LNE route had decided that any reduction in the number of posts in track inspection, due to the introduction of PLPR, would result in a corresponding increase in the number of posts in the track maintenance teams.

136 Running for a prolonged period with a reduced number of staff in the track maintenance team had affected the amount and type of maintenance work that the team carried out. Due to the workload generated by the number of track geometry faults in this area (paragraphs 129 to 130), the team spent most of its time carrying out reactive repairs. However, this did not deliver a reduction in the number of faults as many recurred because the repairs were ineffective (paragraphs 113 to 118). Witness evidence indicates this left very little time for the team to do basic preventative maintenance work, so the condition of the track assets deteriorated over time and new faults developed.

137 Around March 2014, TSM2 returned to work (paragraph 110) and lodged a grievance with Network Rail over the prolonged shortfall in the number of staff within his maintenance teams. He agreed with his line management to resolve the grievance locally. An independent person from the RAM (track) team heard the grievance and led a review to estimate the resource levels needed to maintain the track assets in the Track Section Manager's area. The review looked at the age and condition of the track assets and from this identified an annual amount of track inspection and maintenance work that needed to be done, taking into account its priority and any refurbishment or renewal work that was planned. From these maintenance volumes, the review calculated an estimated number of man hours required to deliver it, which was then converted to an equivalent headcount. The review identified a headcount of between 36 and 37 maintenance staff was needed. This figure was very close to the 35 maintenance staff that the phase 2b/c organisation had identified were needed.

138 Later in 2014, two vacancies were filled by Network Rail apprentices. Around the middle of 2014, the IMDM agreed that a further five vacancies could be filled. TME1 and TSM2 followed Network Rail's process for recruiting into these vacancies, which were subsequently advertised, interviews held and five people were selected. However, in September when Network Rail's Human Resources function was asked to issue job offer letters, it told TME1 and TSM2 these posts could not be filled as they were being 'consulted out of the business'. This meant the vacancies had been identified by Network Rail as no longer being required as part of a phase 2b/c post implementation review, and subject to negotiations with the trades unions, would be removed from the organisation template.

139 The phase 2b/c post implementation review had taken place during 2013. Network Rail's corporate centre asked each Route to look at whether its phase 2b/c maintenance organisation met its needs by looking at things such as the appropriateness of roles and the sizing of the various teams across all of the maintenance disciplines. The review also looked at efficiencies and included work to understand if the vacant posts within the maintenance organisation were needed. Witness evidence states that when vacancies were reviewed, the Route asked each IMDM to identify about 23 of their vacant posts that could be given up. At the time the Newcastle IMDM was holding various vacancies, including some in the Newcastle Track Section Manager organisation which he intended to fill once PLPR had been introduced. Although the IMDM did not want to give up any of the Newcastle Track Section Manager vacancies he was holding, he identified them as posts that could be given up if it was necessary. However, once these posts were identified, the Route deemed them to have effectively been given up so they could no longer be filled.

140 The consistently high levels of track geometry faults and eighth of a mile sections of track in the super-red band were indicators that the Newcastle Track Section Manager organisation was struggling to maintain its track assets (paragraphs 129 to 131). In 2013, TME2 was challenged by the Route's senior management to reduce the number of track geometry faults. TME2 put forward a case for extra resources and was given budget for a team of eight contractors. This contract labour gang, led by a Network Rail team leader, was used to target track geometry faults at specific locations across both the Newcastle and Middlesbrough Track Section Manager areas. Its remit was to carry out repairs that were longer lasting so the fault would not repeat. This contract labour was provided at about the same time that the vacancies in the Newcastle maintenance team were identified for consultation out of the business.

141 In 2014, TME1 and the IME recognised that even if the vacancies in the Track Section Manager's team were filled (paragraph 138), a larger workforce was needed if they were going to reduce the number of track geometry faults they had. In May, they made a case to senior managers on the Route for hiring further contract labour. In response, TME1 was given permission in July to hire another team of eight contractors. TME1 used the new contract labour gang, again led by a Network Rail team leader, to target track geometry faults across both the Newcastle and Middlesbrough Track Section Manager areas. The existing eight contractors were redeployed within the Network Rail maintenance teams to boost their numbers closer to the levels in the phase 2b/c organisation.

142 TME1's case for retaining contract labour was strengthened in September following a visit by a senior manager from Network Rail's corporate centre. This manager had visited sites in the Newcastle area to carry out a peer review of planned track renewal proposals. During these visits, he noticed while walking the track that basic preventative maintenance and routine interventions were not being adequately achieved for track assets. He also observed that there were rail defects which should have been preventable, voiding and alignment faults were not being permanently corrected and there were increasing numbers of track geometry faults. Among the reasons for these observations he noted issues with the availability of staff to do maintenance work. The manager reported his concerns in a letter to TME1, which was copied to the RAM (track) and IMDM.

143 By the time of the derailment, TME1 was beginning to see the benefits of his maintenance staff being supplemented by 16 contractors, with reducing numbers of track geometry faults in his area. However, due to the significant volume of defects that still needed to be repaired, the wet beds and track geometry faults at Heworth had not yet been repaired as other faults were prioritised ahead of them.

Safe systems of work

144 When track maintenance work is planned, section planners are required to select a safe system of work from a hierarchy listed in Network Rail standard NR/L2/OHS/019. The safest system of work (at the top of the hierarchy) is a safeguarded green zone in which all lines within the site of work are blocked to train movements. The least safe system (at the bottom of the hierarchy) is working on a line that is open to traffic (called red zone working in standard NR/L2/OHS/019) with *lookout* warning.

145 Over the last 10 years Network Rail has been aiming to reduce the extent of red zone working by encouraging staff to actively consider other ways of protecting track workers (such as temporary blockages of the line) and to limit the selection of red zone working to those cases where there is no practical alternative. However, in 2013 the majority of track maintenance work in the Newcastle Track Maintenance Engineer's area was still being carried out using red zone working.

146 In September 2013, following a number of incidents and near misses in the Newcastle Delivery Unit area involving maintenance staff using red zone working, the ORR (see appendix A for definition) issued an improvement notice on Network Rail, relating specifically to the Newcastle Delivery Unit. It called upon the Delivery Unit to 'carry out a suitable and sufficient assessment of the risks to employees (from all disciplines) from trains to determine how the risks can be reduced so far is reasonably practicable'. The improvement notice suggested a range of actions that encouraged carrying out inspection activities using a safer system of work from the hierarchy. It also required sighting distances to be accurately measured so that red zone working would no longer be allowed in places with inadequate sighting distances or if red zone working with lookouts or by an *individual working alone* (IWA) was permitted, the sighting distances took into account changes such as the seasonal growth of vegetation.

147 Changes made by Network Rail in response to the improvement notice affected much of the red zone working that remained. A lot of existing red zone working with lookout protection required an increased number of lookouts and work previously carried out by an IWA now required one or more lookouts to be provided. The increase in staff needed for protection duties caused a corresponding decrease in the number of staff available to do the actual maintenance work. However, this was mitigated, in part, by changes to move away from red zone working and take line blockages instead, which removed the need for any lookouts (although someone may be required to warn staff working near tracks that are open to traffic if they move outside their safe working area instead). The Newcastle Delivery Unit now aims to take line blockages for 90% of its maintenance work.

148 The change in working practices from red zone working to line blockages affected the productivity of the Newcastle Track Section Manager's maintenance teams. Witness evidence from track maintenance staff indicated that in the 12 months prior to the derailment, it took time to adjust to working using line blockages, with longer periods spent stood off the track. When using red zone working, staff stood off the track once given a warning for an approaching train and were soon told to resume work once it had passed. When using line blockages, staff stood off so the line blockage could be handed back, the train then passed and the line blockage was taken again. While this provided the staff with a safer system of work, they felt they were spending a lot of time waiting, particularly if there was delay in the signaller giving the line blockage again.

149 Witness evidence also indicates that even when the process for booking line blockages was followed, a signaller could refuse to give the blockage if they had already given out a number of other line blockages or in some cases a team from another maintenance discipline had already taken a line blockage nearby. This stopped staff from getting access to the track, so the maintenance work was then cancelled and had to be re-planned for another time. Work has been ongoing within the Delivery Unit to improve the planning and coordination of work to avoid these types of conflict.

Track access at Heworth

150 Network Rail's data for the amount of tonnage passing over the Down Sunderland line at Heworth shows that it doubled from about September 2010 to January 2014 (figure 31). This was due to a steady increase in the number of freight trains running into and out of Tyne Dock, particularly the loaded trains coming out onto the Down Sunderland line. The increased number of freight trains was not enough to trigger a change in the track's category, which would affect its inspection regime. However, the freight trains ran throughout the day and night and affected the maintenance team's ability to get access to the track.

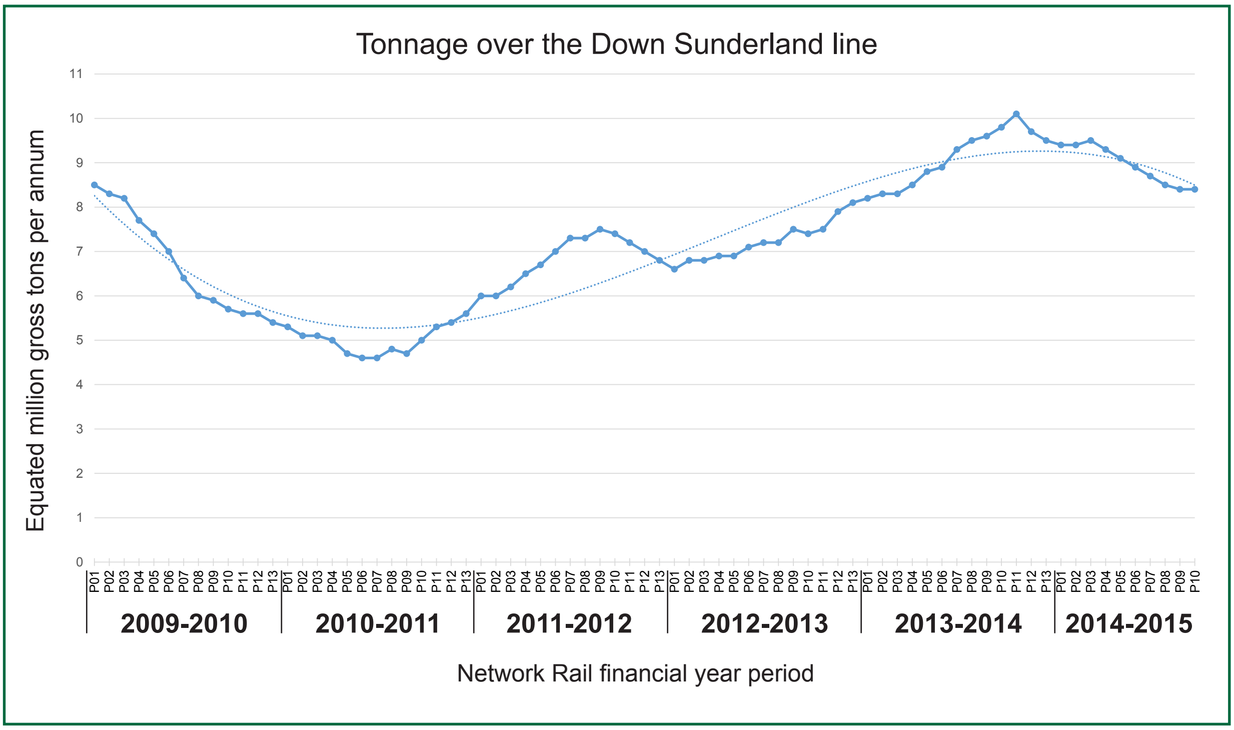


Figure 31: Tonnage over the Down Sunderland line

151 Before the freight traffic out of Tyne Dock started, the track maintenance teams could take possession of the track between Pelaw and Newcastle during the night on most weeks when they needed to. After the amount of freight traffic increased, these possessions could only be taken once every six weeks, leaving less opportunity to do repairs that were planned at short notice.

152 Network Rail's ability to carry out some types of work on the Down Sunderland line was also affected by its close proximity to the Tyne and Wear Metro infrastructure. Work with road rail vehicles or on-track machines can require possessions or isolations of the overhead line equipment on the adjacent Tyne and Wear Metro line. This then requires the cooperation of the Tyne and Wear Metro operator and infrastructure owner when it is planned. Both TSM1 and TSM2 were aware of what was required when planning this type of work, and that it meant there was less opportunity to do this type of work at short notice.

Track inspection changes

153 Changes to the track inspection regime in this area, through the introduction of PLPR technology (paragraphs 35 to 37), generated a significant workload for the track maintenance teams. Trial running began in 2014 and when the PLPR train first ran over the East Coast Main Line between Ferryhill and Newcastle, it reported over 5000 defects. While the majority of these defects were minor, such as track fastenings that were obscured by ballast, it required a significant amount of effort by the maintenance teams to address the reported defects and reduce their number to a manageable level. The trial running of PLPR in this area has highlighted that its introduction can cause a significant increase in maintenance workload at the start.

154 The introduction of PLPR also meant that the track geometry on the Down Sunderland line was being recorded more frequently than required by Network Rail's standards. The Down Sunderland line at Heworth should be recorded every 16 weeks but it was actually being recorded every 12 to 13 weeks (paragraphs 33 to 34). The track maintenance teams were required to action all of the track geometry faults found by the scheduled track geometry recording trains within the timescale defined on the sheet listing the faults.

155 When trial runs by PLPR trains commenced, the track geometry on the Down Sunderland line was being recorded every month and sometimes every two weeks. At first, the track maintenance teams tried to action all of the track geometry faults that were reported. However, sometimes faults requiring action within 14 days or more were not being addressed before the PLPR train ran again. After a while the track maintenance teams were overloaded due to the volume of reported track geometry faults and found they only had time to react to faults reported by track geometry recording trains.

156 To help alleviate this situation, during 2014 TME1 made changes so that the track maintenance teams would only respond to track geometry defects that fell into an immediate action category, plus category A and B cyclic top faults too (table E1 in appendix E shows these require a 30 mph (48 km/h) emergency speed restriction to be imposed within 36 hours, followed by repair within a specified number of days). All of the other track geometry faults reported by PLPR trains would be used for information only, such as top faults that otherwise would have required repair within 14 days.

Audit and self-assurance framework

157 Network Rail's management processes for audit and self-assurance did not identify that the Newcastle Track Section Manager organisation was not complying with Network Rail's processes for track maintenance.

158 Network Rail's current standard NR/SP/ASR/036, 'Network Rail Assurance

Framework', defines a hierarchy of auditing, supplemented by inspections by managers and supervisors, which aim to confirm compliance with Network Rail's own processes. During the RAIB's investigation of a derailment at Paddington station (report 03/2015), Network Rail reported that this process was being replaced with a revised assurance framework. This started in 2012/2013.

159 Network Rail's revised assurance framework defines three levels of auditing and self-assurance arrangements. Its corporate audit programme (level 1) tends to focus on key strategic topics across the company. Below this is the functional audit programme (level 2), which is the highest level that a maintenance delivery unit will be subjected to. The functional audit programme is led by an auditor and is supported by engineers from other Routes. It covers the audit of management systems, track, signalling and telecommunications, and electrification and plant. These audits happen about every three years and August 2012 was the last time the Newcastle Delivery Unit was subject to one of these audits.

160 In August 2012, the track component of the audit was carried out by an independent auditor from London North Western Route. The auditor noted nine minor non-compliances covering a range of issues. Three of the non-compliances did not apply to the Newcastle Track Section Manager area and none were noted as a direct result of the audit of the Newcastle Track Section Manager organisation. When this audit took place, processes such as record keeping and data entry on Ellipse were being followed within the Newcastle Track Section Manager organisation. The RAIB found that most of the problems related to the management of records on Ellipse coincided with the absence of TSM2 and Section Administrator from the start of 2014 (paragraph 110). However, the RAIB found some longer term problems such as inspections for eighth of a mile sections of track with SD values in the very poor or super-red bands not taking place (paragraph 102), the findings from supervisor cab rides were not documented and the record for the last Track Maintenance Engineer inspection at Heworth in 2013 was missing (paragraph 106). It also found that no records were kept when the maintenance teams responded to rough ride reports (paragraph 108).

161 The next level of the assurance framework (level 3) is carried out within the Route and is based on self-assurance, ie it is the responsibility of the Route to audit itself and confirm it is complying with Network Rail's processes. This is intended to cover all of the functions within a delivery unit. The self-assurance process within the Newcastle Delivery Unit did not lead to the identification of the non-compliances by the Newcastle Track Section Manager's organisation as described in the previous paragraph.

162 The assurance framework as a whole did not make any of the senior management within LNE Route, or at Network Rail's corporate centre, aware of the number of non-compliances within the Newcastle Track Section Manager organisation.

163 While the assurance framework should identify when a process is not being complied with, it does not consider the condition of the track assets or how they are being maintained, ie the quality of the maintenance work being delivered or whether the maintenance being carried out is appropriate. The RAM (track) team does not check the quality of maintenance work either as it does not have sufficient resources to do this. The site visits it carries out are primarily focused on looking at asset condition in terms of renewals (both for planning a renewal and checking what has been delivered by a renewal).

164 The day-to-day task of checking the quality of the track maintenance being achieved is primarily down to the Track Maintenance Engineer and the Track Section Manager and his supervisors. Any checks of this type tend to happen when their mandated inspections take place. The high workload meant that neither role had the time to carry out specific site visits to audit the quality of maintenance work carried out by their maintenance teams.

Observations

165 **A 50 mph (80 km/h) emergency speed restriction was not applied for the vertical track geometry that was repeatedly recorded during 2014 with a SD value in the super-red band on the Down Sunderland line at Heworth.**

166 The overall poor quality of the vertical track geometry on the Down Sunderland line at Heworth, for the eighth of a mile section from 99 miles 220 yards to 99 miles 440 yards, meant that Network Rail should have imposed a speed restriction to comply with NR/L2/TRK/001/mod11. Figure 26 shows a chart for the SD value bands recorded for the last ten track geometry recording runs over the point of derailment, up until August 2014. It shows how the SD value for the eighth of a mile section where the derailment happened had worsened over time.

167 By February 2014, its SD value was recorded in the maximum band, the 'super-red' category and it remained a super-red for the next two track geometry recording runs in May and August. Once this eighth of a mile section became a super-red, NR/L2/TRK/001/mod11 required TME1 to take action to improve its quality. When TME1 reviewed the track recording trace in February, he actioned the TSM2 to carry out an inspection to support this, but it did not take place as TSM2 was off work due to illness at the time (paragraph 110). NR/L2/TRK/001/mod11 states that if the action undertaken is not sufficient to move the SD value out of the maximum band then a speed restriction must be imposed.

168 After both the May and August runs, due to its continuing poor quality, Network Rail should have reduced the permitted speed over that eighth of a mile section of the Down Sunderland line to 50 mph (80 km/h) in accordance with the requirements of NR/L2/TRK/001/mod11. TME1 did not identify that this needed to be done when he reviewed the output from these runs. TSM2 did not either as he did not inspect the track after the May run. He did inspect it after the August run and while he called for action to be taken to repair the track (paragraph 105), he decided it was fit for trains to pass over it at line speed, and did not identify that NR/L2/TRK/001/mod11 required a speed restriction to be applied.

169 If this speed restriction had been in place, so that train 6S26 passed over the cyclic top at 50 mph (80 km/h), it would not have affected the outcome as the train was travelling at 51 mph (82 km/h) when it derailed. Therefore the RAIB has noted the non-application of this speed restriction as an observation.

Previous occurrences of a similar character

Derailments

170 In the past, derailments involving two-axle vehicles with a short wheelbase (up to about 6 metres) on cyclic top track defects were reasonably commonplace. This type of wagon was known to be susceptible to this type of track geometry defect. However, over the past 10 to 15 years, there have been fewer of these derailments. This is partly due to a significant reduction in the number of short wheelbase two-axle wagons and partly due to changes in track maintenance, such as improved track geometry recording and the use of stoneblowing.

171 The RAIB has investigated three previous derailments that were caused by cyclic top. The first was an ultrasonic test vehicle, a two-axle vehicle with a short wheelbase, which occurred at Cromore in Northern Ireland (RAIB report 42/2007). The second was a two-axle wagon, which occurred at Castle Donington (RAIB report 02/2014). The third was a container flat wagon, which occurred near to Gloucester (RAIB report 20/2014). The RAIB has also investigated a freight train derailment at Marks Tey (RAIB report 01/2010) where a container flat wagon derailed on a series of dips in the track.

172 The RAIB carried out a search of the Safety Management Information System[6] for derailments involving freight trains on cyclic top track defects. The search found ten derailments of two-axle wagons between 1997 and 2014 as a result of cyclic top track defects (entries for a further four derailments did not identify the type of wagon that had derailed). None of these involved PCA wagons.

173 The RAIB has also investigated two previous derailments that have involved two-axle wagons fitted with Gloucester pedestal suspensions. The first was a hopper wagon (type PHA), which occurred at Ely Dock Junction, where the wagon derailed on a track twist while its suspension was locked up in one position, which prevented it from responding to a track twist (RAIB report 02/2009). The second was again a PHA wagon with a locked up suspension that derailed on a track twist, which occurred at Bordesley Junction (RAIB report 19/2012).

[6] The Safety Management Information System (SMIS) is the rail industry's national database for recording safety-related events that occur on the United Kingdom main line rail network. It is facilitated by RSSB on behalf of the rail industry.

Staffing levels

174 The RAIB's investigation for a freight train derailment near Gloucester (RAIB report 20/2014) included an observation about unfilled vacancies within the Gloucester Track Section Manager organisation. As a result, in September 2014 the RAIB wrote to Network Rail about its staffing levels. As well as Gloucester, there were a number of completed and ongoing RAIB investigations in which staffing levels and associated high workload had featured in some way, whether causal or not. Examples cited in the letter included Clapham and Earlsfield (RAIB report 03/2012), Littleport (RAIB report 06/2013), Bulwell (RAIB report 20/2013), Denmark Hill (RAIB report 23/2014), Bridgeway crossing (RAIB report 25/2014), Stoke Lane crossing (RAIB report 02/2015) and Redhill (RAIB report 06/2015).

175 The letter drew Network Rail's attention to this. It asked Network Rail to give serious consideration to staffing levels and associated excessive workload because of the potential for such issues to be causal to accidents and incidents in the future.

Previous RAIB recommendations relevant to this investigation

176 The following recommendations (in chronological order), which were made by the RAIB as a result of its previous investigations, have relevance to this investigation.

Recommendation that was being implemented at the time of the accident

Derailment at Santon, near Foreign Ore Branch Junction, Scunthorpe, 28 January 2008, RAIB report 10/2009, Recommendation 7

177 The recommendation below addressed two of the factors identified in this investigation (track geometry faults repeatedly found by the track inspection regime (paragraph 97) and ineffective repair of track geometry faults (paragraph 113)). So as to avoid duplication, it is not remade in this report.

Recommendation 7

Network Rail should implement processes to investigate and monitor the effectiveness of repairs to repetitive track geometry faults, so that when a track geometry fault recurs, the reason for it coming back can be established, an appropriate repair method can be chosen and monitoring can be carried out to determine whether the second attempt to repair it has been successful.

178 The above recommendation was also reiterated by the RAIB's investigation of a freight train derailment at Bordesley Junction, Birmingham, 26 August 2011 (paragraph 173) and by the RAIB's investigation of a freight train derailment at near Gloucester, 15 October 2013 (paragraph 171).

179 In 2009, Network Rail reported to the ORR that it considered its track geometry reporting system already contained an operational repeat faults report and that more use should be made of it. However, Network Rail was also reviewing the processes and expectations for using this system, with a timescale for completion in 2010. By July 2012, the ORR informed the RAIB that Network Rail had begun developing a new system to support the identification and investigation of repetitive track geometry faults. Network Rail trialled this system, known as LADS (Linear Asset Decision Support) between August and December 2012 and implemented it nationally in 2013 and 2014. Roll out across all of its Routes was completed by the end February 2014.

180 While LADS was being developed, Network Rail had established a team to develop and promote the use of defined repair methods for specific types of defect to improve the quality and reliability of a range of maintenance work. This work was focused on track geometry repairs. The team had produced guidance in NR/GN/TRK/7001 (appendix E, paragraph E7) and videos which have been briefed out to Track Maintenance Engineers and Track Section Managers, and used to train and support staff at maintenance depots.

181 In November 2013, the ORR served an improvement notice on Network Rail Scotland Route in relation to repeat track geometry faults, in particular track twist. The ORR reported to the RAIB that work by Network Rail to repair a significant number of track twists was not effective in preventing a re-occurrence. The ORR did not consider Network Rail had appropriate arrangements in place to ensure the risk arising from these track geometry faults was controlled. At this time, the ORR advised the RAIB that Network Rail needed to take action to address the improvement notice and comply with it before the intent of Santon recommendation 7 could be met.

182 Part of Santon recommendation 7 called for Network Rail to monitor the effectiveness of repairs to repeat track geometry faults. The ORR reported in September 2014 that Network Rail had not introduced any additional monitoring by supervisors beyond that already required by its standards for track inspection[7]. However, in response to the improvement notice served on it by the ORR, Network Rail Scotland Route had developed an action plan which included tasking Track Section Managers to go to site and inspect the fault beforehand, and then to check the quality of repair work afterwards and assess if it was effective. The action plan applied to all immediate action level faults that were repeats, plus all other track geometry faults that required maintenance intervention which had repeated two or more times. The ORR reported that by October 2014 Network Rail Scotland Route had addressed the actions required by the improvement notice.

183 Network Rail Scotland Route shared information about the actions it had taken, including these additional monitoring arrangements for repeat track geometry faults, with all of the other Routes. This was to allow the other Routes to consider how they might wish to implement these actions. Separately, Network Rail introduced targets for all of its Route Asset Managers (track) to reduce the number of repeat track geometry faults, with actions passed down as necessary to the Track Maintenance Engineers and Track Section Managers. On Scotland Route, progress was monitored at review meetings held every four weeks, which were attended by the Infrastructure Maintenance Engineer, Track Maintenance Engineer and Track Section Manager. Other Routes developed their own monitoring arrangements. As part of a targeted inspection programme, the ORR reported it had seen increased focus on improving the management of risk arising from track geometry faults, through a range of locally driven initiatives at Track Maintenance Engineer and Track Section Manager level. The ORR reported it had also continued to monitor Network Rail's number of repeat track geometry faults and had seen a decrease. By July 2015, the ORR was satisfied that Network Rail had taken sufficient action to implement the requirements of Santon recommendation 7. In August 2015, the ORR reported to the RAIB that this recommendation was now implemented.

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[7] NR/L2/TRK/001/mod11 issue 6 required all repeat track geometry faults that fell into the immediate action limit category to be inspected by a supervisor within 14 days. Supervisors were not required to inspect other repeat track geometry faults that needed maintenance intervention. For these repeat faults, NR/L2/TRK/001/mod11 issue 6 requires the Track Maintenance Engineer to identify them as repeats when reviewing the output from each run by a track geometry recording train. The standard called for these review findings, along with the findings from other track inspections, to be used to create a maintenance plan to reduce the number of intervention level faults repeating. The standard did not state what actions should be included in the plan in order to achieve this.

184 At the time of the derailment, Network Rail LNE Route did not have any specific arrangements in place for managing repeat track geometry faults as called for by Santon recommendation 7. Although TSM1 and his supervisors knew the fault at Heworth was a repeat, they did not monitor the effectiveness of any repair work as they had no time to do so (paragraph 164). Had this happened, they would have known that the repair was unsuccessful and could have taken a different course of action for the worsening cyclic top defect, such as prioritising the removal of the wet beds and imposing a speed restriction in the interim, but they did not (paragraphs 78 to 83).

Recommendations that are currently being implemented

Derailment at Bordesley Junction, Birmingham, 26 August 2011, RAIB report 19/2012, Recommendation 2

185 The recommendation below addressed one of the factors identified in this investigation (worn components within the Gloucester pedestal suspension (paragraph 46)). To avoid duplication, it is not remade in this report.

Recommendation 2

Network Rail through its Network Certification Body, and in conjunction with Lafarge Aggregates Ltd and Wabtec Rail Limited, should lead a fundamental review of how the suspension of the PHA wagon is maintained. The review should call upon relevant technical expertise to:

- *look at how the suspension works as a whole and understand the role that each individual component performs; and*
- *use this knowledge to document the actions for maintaining a fully functioning suspension, which may include monitoring, measuring and setting limits for the permitted overall amount of wear in the suspension and also individual component wear, including specific actions and limits set to account for those components that are not fully visible when the wheelset is in place.*

Once the review has decided what actions it is reasonable to take, they should be implemented in the maintenance plans for the PHA wagon fleet.

186 While the above recommendation was addressed to organisations with responsibilities linked to the PHA wagon fleet, the RAIB noted that it may also apply to organisations that owned or operated other types of wagon fitted with Gloucester pedestal suspensions. Freightliner, as the owner, maintainer and operator of the PCA wagon fleet, was aware of this recommendation.

187 In December 2013 the ORR reported to the RAIB that Network Rail's Network Certification Body (in conjunction with Lafarge Aggregates Ltd, Wabtec Rail Limited and other industry experts) was planning to carry out a review of the suspension that aimed to understand the influence of modifications they had identified and made to the suspension on the PHA wagons. This would include a review of the suspension's maintenance regime. The timescale for this review had moved back due to Network Rail's Network Certification Body continuing to work alongside the wagon owner and maintainer to collect data on how modified and unmodified suspension components were wearing while in service. This data was taking longer to collect due to a slippage in the programme to modify the PHA wagon fleet. Network Rail's Network Certification Body wanted this data to make an informed evaluation of the extent that suspension components were wearing, so the maintenance requirements could then be understood.

188 The ORR reported that it was continuing to monitor progress with the implementation of this recommendation, and while it agreed with the approach, it was concerned over the time being taken. The ORR acknowledged that the progress being made by Network Rail's Network Certification Body was reliant on the programme to modify the suspension on the wagons.

189 The suspension modifications to the PHA wagons are focused on reducing the likelihood of the suspension locking-up (this is when the saddle sticks and stops moving inside the pedestal). The information provided by the ORR shows that Network Rail's Network Certification Body actions to implement this recommendation are aimed at delivering revisions to the maintenance regime that take the requirements of the modified suspension into account. The intent of this recommendation was to prevent a wagon from entering service with worn suspension components, which could increase the likelihood of the suspension locking-up, through a fundamental review of how the suspension components wear. It included looking at how the suspension works as a whole and understanding the role that each individual component performs. Using this knowledge, it aimed to document the regime needed to maintain a fully functioning suspension. This information would then be used to update the maintenance plans for the PHA wagon fleet.

190 This fundamental review of the suspension has not yet taken place. Had such a review taken place, it might have considered what effect a worn damper pad would have on the operation of the suspension (ie it would result in a loss of damping within the suspension rather than it locking-up) and how a worn damper pad could be detected by the maintenance regime. While Freightliner's vehicle maintenance instructions already specify a damper pad wear limit, which relates to the depth of hardened material in a damper pad (paragraph 58), wagon 10769 was operating in service with a damper pad that was worn beyond this limit. The common issue, found by both this investigation and the Bordesley Junction investigation, is how to ensure the maintenance regime will detect worn components within the Gloucester pedestal suspension between VIBT examinations, particularly those components which cannot be seen or measured when the wheelset is in place.

191 Since 2007, Freightliner has carried out work to improve the fleet's maintenance regime. Freightliner has reported to the RAIB that after the derailment at Bordesley Junction, it independently undertook a thorough review of its maintenance policy for the Gloucester pedestal suspension. As a consequence, Freightliner revised its maintenance policy in 2012 to mandate that both wheelsets were removed from each wagon at its annual VIBT examination so that pedestal and saddle friction liner plate wear could be effectively measured. These changes also mandated reduced wear limits for the friction liner plates. After the derailment at Bordesley Junction, Network Rail's Network Certification Body had also proposed a number of modifications to the Gloucester pedestal suspension to reduce the likelihood of the suspension locking-up on PHA wagons. Freightliner had implemented these modifications to its PCA wagon fleet.

Freight train derailment near Gloucester, 15 October 2013, RAIB report 20/2014, Recommendation 2

192 The recommendation below addressed two of the factors identified in this investigation (ineffective repair of track geometry faults (paragraph 113) and inadequate application of emergency speed restrictions for cyclic top (paragraph 78)). To avoid duplication, it is not remade in this report.

Recommendation 2

Network Rail should revise its processes for the management of cyclic top track defects. It should:

a) *review the requirement that immediate action cyclic top track defects must be repaired within 36 hours to understand if it is feasible for an effective repair to be made in this timescale, and if not, mandate the actions that must be taken to mitigate the risk due to the cyclic top track defect until an effective repair can be planned and made;*

b) *provide guidance, which is briefed out to its track maintenance staff, on how to make effective repairs to cyclic top track defects. This guidance should tell track maintenance staff not to carry out manual repair work that is only aimed at breaking the cyclic top track defect into sections of track with poor vertical track geometry, unless the risk presented by the residual poor vertical track geometry is assessed and mitigating actions taken (such as the imposition of a speed restriction);*

c) *review the adequacy of its processes for imposing and removing emergency speed restrictions applied for cyclic top track defects. This is to assure itself that there are adequate controls in place for the removal of cyclic top related speed restrictions. Such controls could include an assessment of the track's vertical geometry, carried out after trains have run over the repaired track, but before line speed is restored; and*

d) *have a process in place that raises the visibility of repetitive cyclic top track defects, so that senior management responsible for the local maintenance team are made aware of it and can monitor the actions being taken to address the cyclic top.*

193 When the derailment at Heworth happened, Network Rail had not taken any steps to implement this recommendation as the RAIB report was only published about one week before. While the RAIB has not yet received any correspondence from the ORR about what Network Rail intends to do to implement this recommendation, it is aware that in June 2015, Network Rail issued a letter of instruction, NR/BS/LI/350, that mandated changes to how cyclic top faults are managed. NR/BS/LI/350 specifies changes to the requirements in NR/L2/TRK/001/mod11 so that for cyclic top faults, such as the one at Heworth, a 30 mph (48 km/h) emergency speed restriction must be imposed over it until monitoring has shown that the track maintenance team has made an effective repair. The requirements in NR/BS/LI/350 have been incorporated into a revised version of NR/L2/TRK/001/mod11 which was published in September 2015 and has a compliance date of December 2015.

194 The RAM (Track) on LNE Route had just seen the RAIB's report for Gloucester when the derailment happened at Heworth. In response to both, he decided to mandate actions on LNE Route that immediately delivered the intent of parts a and c of this recommendation. TME1 then expanded the scope of this instruction to also include category A and B cyclic top defects (see paragraph 199).

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

Freightliner

195 In November 2014, Freightliner issued a special check for its PCA wagons with 'Mark 2' suspensions which maintenance staff then carried out to identify any wagons that may have a suspension with reduced damping (paragraphs 53 to 54). This check identified four wagons for further investigation, two of which were found to have a severely worn damper pad on one corner. Freightliner removed both wagons from service to carry out further investigations to check the alignment of their wheelsets and pedestals. The suspension components on one wagon were examined and its damper pads were unworn so it was returned to service. Freightliner reports that it is developing a way of measuring the pedestal alignment and is using the other wagon to do this.

196 While this check identified those wagons with a worn damper pad at that point in time, it is possible that the check did not identify all of the PCA wagons which are prone to high levels of damper pad wear. If such a wagon had undergone a recent VIBT examination and had new damper pads installed, it is unlikely that any of its damper pads would have worn enough by that time to allow any movement to be detected by the check. However, one of its damper pads could become severely worn by the time its next VIBT examination is due. When it derailed, wagon 10769 had been in service for about nine months since its last VIBT examination. Freightliner reports that it has continued to monitor its PCA wagon fleet for any high levels of damper pad wear by measuring the damper pads removed from each wagon at every VIBT examination. By the start of September 2015, Freightliner had not found any damper pads that were worn beyond their maintenance limit. In September 2015, Freightliner stated to the RAIB that it will continue to measure damper pad dimensions and review the information gathered.

197 Since this derailment, Freightliner has also reviewed its PCA wagon maintenance instructions to identify what changes it can make to improve the maintenance of these wagons. This work has clarified where suspension components should be measured and how many measurements should be taken. Freightliner reports that it has also provided its maintenance staff with new tools and equipment for measuring the suspension components.

Network Rail

198 Immediately after this derailment Network Rail made a temporary repair to the track on the Down Sunderland line at Heworth. Track maintenance staff placed new ballast on top of the track where the ballast was most contaminated and a tamper lifted the track and packed the new ballast under the sleepers. Before the line was reopened, TME1 imposed a 20 mph (32 km/h) emergency speed restriction from 99 miles 110 yards to 99 miles 1056 yards, which included the point of derailment and further poor vertical track geometry with wet beds near to Felling.

199 Soon after the derailment, and the publication of the RAIB report on a derailment near Gloucester (report 20/2014), the RAM (track) for LNE Route mandated the track maintenance teams to impose an emergency speed restriction straight away for all immediate action cyclic top defects reported by track geometry recording trains (paragraph 194). This stopped the practice of track maintenance teams attempting to repair a significant defect, using ineffective manual repair methods, within a short timescale, to avoid imposing a speed restriction. He also mandated that once repaired, Track Section Managers, or their supervisors, must watch the track under traffic for a further seven days to show that the repair has been effective before the emergency speed restriction can be removed. TME1 expanded the scope of this by instructing his Track Section Managers to respond in the same way for all category A and B cyclic top defects reported by track geometry recording trains.

200 During April and May 2015, Works Delivery continued its work to install new track drainage at Heworth heading towards Pelaw, from 98 miles 1435 yards to 98 miles 1216 yards. Further work is planned in August 2015 to complete the renewal of the drainage from 99 miles 176 yards to 99 miles 319 yards. This will correct the problems that had been found with it (paragraph 90).

201 Since the derailment Network Rail has continued to supplement the Newcastle Track Section Manager's teams with contract labour. Eight contractors are still working within the track maintenance teams to boost staff numbers. Another six contractors have been brought in to boost the Middlesbrough Track Section Manager's staff numbers. A further eight contractors, led by a Network Rail team leader, are still being used to target track geometry faults as directed by TME1. TME1 has noted the benefits of having these extra resources, with a steady decrease in the number of track geometry faults in his area (from over 650 at the time of the derailment to about 450 in June 2015). However, due to the high number of defects to start with, his area still has the highest number of track geometry faults on LNE Route.

Summary of conclusions

Immediate cause

202 The leading left-hand wheel of PCA wagon 10769 climbed onto the head of the rail and derailed (**paragraph 43**).

Causal factors

203 The causal factors were:

a. The wheel on the leading right-hand corner of wagon 10769 was not sufficiently damped due to a worn damper pad in its suspension, which made the leading left-hand wheel on the wagon susceptible to unloading when responding to changes in vertical track geometry (**paragraph 46**; see also Bordesley Junction recommendation 2 (paragraph 185)). This causal factor arose due to one of the following factors:

   i. It is possible that a damper pad that was already close to the wear limit was installed at the last VIBT examination (**paragraph 63, Recommendation 1**); or

   ii. It is probable that a problem with the alignment of the leading wheelset within its suspension caused excessive damper pad wear while also increasing the propensity of the wagon to derail (**paragraph 67, Recommendation 1**).

b. The ballast on the approach to the point of derailment on the Down Sunderland line was heavily contaminated with slurry, resulting in wet beds and vertical track geometry faults that required maintenance action, including a cyclic top defect which should have resulted in the imposition of an emergency speed restriction (**paragraph 74**). This causal factor arose due to a combination of the following factors:

   For the emergency speed restriction:

   i. A 30 mph (48 km/h) emergency speed restriction was not applied for a cyclic top defect on the Down Sunderland line at Heworth, which allowed train 6S26 to pass over the cyclic top at up to its maximum speed of 60 mph (97 km/h) (**paragraph 78**; see also Gloucester recommendation 2 (paragraph 192))

   For the cyclic top defect:

   ii. Water was present in and under the track bed (**paragraph 85, Recommendation 2**).

   iii. The wet beds and resulting vertical track geometry faults at Heworth were repeatedly found by the track inspection regime, but other than mandated reactive repairs in response to faults reports from track geometry recording trains, no repairs were planned or took place (**paragraph 97, Recommendations 3 and 4**; see also Santon recommendation 7 (paragraph 177)).

iv. The limited amount of reactive repair work that took place at Heworth was done to sign off reported track geometry faults, which had to be completed within a short timescale, but these repairs were ineffective (**paragraph 113, Recommendations 4 and 5**; see also Gloucester recommendation 2 (paragraph 192)).

v. The track at Heworth had not been renewed in 2013 as intended and the mitigations identified following this track renewal shortfall were not carried out (**paragraph 119, Recommendations 4 and 5**).

Underlying factors

204 The underlying factors were:

a. The Newcastle Track Section Manager's team was unable to cope with the amount of track maintenance work it had to do (**paragraph 128, Recommendation 4**). This underlying factor arose due to a combination of the following factors:

i. Reduced numbers of staff over a prolonged period affected the amount of preventative track maintenance that was carried out (paragraph 133).

ii. Changes to the safe systems of work used for protecting staff carrying out track maintenance affected the amount of work that was carried out (paragraph 144).

iii. Restrictions on gaining access to the track in the Heworth area affected the amount of track maintenance that was carried out at this location (paragraph 150).

iv. Changes to track inspection increased the workload of the Newcastle Track Section Manager organisation (paragraph 153).

b. Network Rail's management processes for audit and self-assurance did not identify that the Newcastle Track Section Manager organisation was not complying with Network Rail's processes for track maintenance (**paragraph 157, Recommendation 5**).

Additional observations

205 Although not linked to the accident on 23 October 2014, the RAIB observes that a 50 mph (80 km/h) emergency speed restriction was not applied for the vertical track geometry that was repeatedly recorded during 2014 with a SD value in the super-red band on the Down Sunderland line at Heworth (**paragraph 165, Learning point 1**).

Learning points

206 The RAIB has identified the following key learning point[8], which was also made by the RAIB's investigation for a derailment that occurred near to Gloucester (paragraph 171):

1 Network Rail should remind its staff responsible for managing the maintenance of its track (such as Track Maintenance Engineers and Track Section Managers) of the requirements in Network Rail standard NR/L2/TRK/001/mod11 relating to the imposition of a speed restriction due to persistent poor track quality:

- If the vertical track geometry of an eighth of a mile long section of track is recorded in the maximum band (ie its SD value places it in the super-red category) and the remedial work undertaken is not sufficient to move the SD value out of the maximum band, then a speed restriction must be imposed.
- This speed restriction should remain in place until a further repair is made and it is confirmed that the repair work has improved the vertical track geometry (paragraph 205).

[8] '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.

Recommendations

207 The following recommendations are made[9]:

1 *The intent of this recommendation is to reduce the risk of a PCA wagon's ride performance being degraded by a loss of damping within its suspension due to a damper pad which is worn beyond its maintenance limit.*

Freightliner should amend its vehicle maintenance instructions for its fleet of PCA wagons so that each damper pad is removed and measured during the VIBT examination to identify those wagons which have had levels of damper pad wear (on any corner) that exceed the permitted wear limit since the last VIBT examination. For each wagon identified, Freightliner should implement measures to prevent it being used in service with a damper pad that could wear beyond the permitted wear limit before its next VIBT examination. These measures could include:

- additional monitoring or checks for that wagon in between VIBT examinations;
- replacing damper pads on that wagon at an earlier interval; or
- carrying out work to identify and address the reasons why that wagon has had a high level of damper pad wear, such as pedestal or wheelset alignment (paragraphs 203a.i and 203a.ii).

2 *The intent of this recommendation is to reduce the possibility of new track defects developing at Heworth, which could cause a derailment.*

Network Rail should investigate why water is not draining from the track bed in the vicinity of where the train derailed (between 99 miles 220 yards and 99 miles 264 yards on the Down Sunderland line between Pelaw and Newcastle) and implement measures to control the risk of excess water affecting the track's vertical geometry. Such measures could include ballast cleaning, remedial work to improve the effectiveness of the installed track drainage, through to a renewal of the track (paragraph 203b.ii)

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[9] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation, and need to take these recommendations 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, these recommendations are addressed to the Office of Rail Regulation (also known as 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.

3 *The intent of this recommendation is to reduce the risk of derailment in the Newcastle Track Section Manager area due to track defects that are not repaired after being found by the inspection regime.*

Network Rail should review the condition of the track assets in the area covered by the Newcastle Track Section Manager against the records on its system for maintaining its track assets (Ellipse). The aim of the review should be to identify track defects requiring maintenance action which are either not recorded on Ellipse, do not have a planned date for repair, or have not been correctly prioritised for repair. Once identified, these defects should be recorded on Ellipse, prioritised and given a date for repair (paragraph 203b.iii).

4 *The intent of this recommendation is to reduce the risk of derailment due to track assets not being maintained by better understanding the reasons for the problems found in this investigation.*

Network Rail should investigate why its track assets within the area covered by the Newcastle Track Maintenance Engineer consistently have the highest numbers of reportable track geometry defects and sections of track in the super-red category on LNE Route. The investigation should include consideration of:

- the number of staff needed to maintain the track assets in the Newcastle Track Section Manager area, so that both reactive and planned volumes of preventative maintenance activities are delivered;
- the effect that changes to safe systems of work used by the track maintenance teams has had on the time spent working on the track;
- the effect that the introduction of PLPR within the track inspection regime has had on increasing the track maintenance workload;
- the types and numbers of track assets in the Newcastle Track Maintenance Engineer's area, their age, and their condition, in comparison to the other Track Maintenance Engineer areas on LNE Route; and
- the effect that any other factors have had in contributing to the high number of track asset defects.

Based on the findings of the above investigation, Network Rail should determine what the appropriate target values are for the numbers of reportable track geometry defects and sections of track in the super-red category in the Newcastle Track Maintenance Engineer area. Network Rail should then take action to improve the maintenance of the track assets in this area to a level that allows these targets to be met (paragraphs 203b.iii, 203b.iv, 203b.v and 204a).

continued

5 *The intent of this recommendation is to reduce the risk of derailment due to track assets not being maintained by better management through auditing and monitoring procedures.*

Network Rail should investigate why its management arrangements allowed non-compliances to processes for track asset maintenance to go undetected in the area covered by the Newcastle Track Maintenance Engineer, which correspondingly had the highest numbers of reportable track geometry defects and eighth of a mile sections of track in the super-red category when compared to other areas. The investigation should include consideration of:

- why its audit and self-assurance framework did not identify the full extent of the non-compliances to processes found by the RAIB;
- why its reporting and monitoring processes did not trigger earlier action by senior management within the Route to resolve the persistent problems affecting the track assets in the Newcastle Track Maintenance Engineer area; and
- whether there are other Track Maintenance Engineer areas, like the one at Newcastle, with persistent non-compliances to processes that are affecting the maintenance of its track assets.

Based on the findings of its investigation, Network Rail should take action to improve the management arrangements at Route level that audit, monitor and review the performance of a local area to highlight non-compliances which are resulting in persistent deficiencies with the maintenance of its track assets (paragraphs 203b.iv, 203b.v and 204b).

Appendices

Appendix A - Glossary of abbreviations and acronyms

BREL	British Rail Engineering Limited
CCTV	Closed Circuit Television
DC	Direct Current
ECM	Entity in Charge of Maintenance
IWA	Individual Working Alone
LNE	London North Eastern Route
ORR	Until 1 April 2015 ORR was known as the 'Office of Rail Regulation'. It has used the name 'Office of Rail and Road' for operating purposes with effect from 1 April 2015. Legal force is expected to be given to this name from October 2015
PLPR	Plain Line Pattern Recognition
PPM	Planned Preventative Maintenance
RAIB	Rail Accident Investigation Branch
RAM	Route Asset Manager
SD	Standard Deviation
TRS	Track Renewal System
VIBT	Vehicle Inspection and Brake Test

Appendix B - Glossary of terms

All definitions marked with an asterisk, thus (*), have been taken from Ellis's British Railway Engineering Encyclopaedia © Iain Ellis. www.iainellis.com.

[signal] Aspect	An indication displayed by a signal.
Basic visual inspection	A visual inspection of the track, carried out on foot, which aims to identify any immediate or short term actions that are required. Often referred to as a track patrol.
Continuous welded rail	A rail of length greater than 36.576m (120'), or 54.864m (180') in certain tunnels, produced by welding together standard rails or track constructed from such rails.*
Damper pad	A component within the suspension that is housed within the pedestal and is pushed against the saddle. The amount of force applied to it determines the amount of friction damping.
Damper pot	A component within the suspension that converts the vertical force on the corner of a vehicle into a horizontal force that pushes on the damper pad to provide the suspension's damping.
Down Sunderland	The name in the report given to the line used by trains travelling in the direction away from Sunderland and towards Newcastle.
Emergency speed restriction	A speed restriction imposed for a short time, at short notice, generally for safety reasons.*
Entity in Charge of Maintenance	A person or organisation responsible for the maintenance of rail vehicles that has to ensure that, through a system of maintenance, a vehicle for which is it responsible is safe to run on the mainline railway.
Fastening	The components of the track which hold the rail in place.
Four foot	The space between the rails of a track.
Individual working alone	A person certified as competent to implement a safe system of work for their own protection on Network Rail controlled infrastructure.
London North Eastern Route	A name for the part of Network Rail's organisation which manages, operates and maintains the railway from London Kings Cross to Berwick upon Tweed (along the East Coast Main Line), including a number of routes that branch off the main line to Lincolnshire, Humberside, Yorkshire including Leeds and Sheffield, Teesside, County Durham and Northumberland.
Lookout	A member of staff whose sole responsibility is to look out for and give warning of approaching trains.
On-track machine	Any piece of specialist railway plant which moves only on the rails and is normally self-propelled.

Pedestal	The vertical guide placed either side of a saddle (axlebox) to restrain it laterally but permit vertical movement of the axle.*
Plain line pattern recognition	A train based technology for carrying out visual inspections of plain line track using cameras to capture images of track components while running up to speeds of 125 mph (201 km/h). Software is used to process the captured images to recognise the track components and identify any associated defects which are output in a report.
Planned preventative maintenance	Maintenance for rail vehicles which is planned to take place on regular basis. It is based on a prescriptive schedule of component replacement, eg brake blocks, or service activities and adjustments, which aim to reduce the incidence of failures in service.
Points	A section of track with moveable rails that can divert a train from one track to another, consisting of a set of switches and a crossing.
Problem statement	A Network Rail document which justifies the need to make an investment in its infrastructure, such as renew a section of track.
Resonance	The oscillation of a system when the excitation frequency is close to its natural frequency.
Road rail vehicle	A road vehicle that has been adapted to make it capable of running on railway track as well as on the road.
Saddle (or axlebox)	The axle bearing housing which connects the wheelset to a rail vehicle via the primary suspension. There is one saddle (or axlebox) at each end of a wheelset.*
Six foot	The colloquial term for the space between two adjacent tracks, irrespective of the distance involved.*
Sleeper	A beam made of wood, pre- or post-tensioned reinforced concrete or steel placed at regular intervals at right angles to and under the rails. Their purpose is to support the rails and to ensure that the correct distance is maintained between the rails.*
Standard deviation	The statistical measure used for quantitative analysis of track geometry recording data, normally calculated per eighth of a mile.*
Stoneblower	An on-track machine that pneumatically injects ballast or chippings to automatically restore the vertical and lateral alignment of the track.

Super-red	A length of track (usually an eighth of a mile) whose recorded standard deviation (SD) value falls in the maximum band, ie the overall quality of its vertical profile or lateral alignment has deteriorated to the point where it now exceeds the upper limit of the very poor band. The SD values for each band are set by the permitted speed over that length of track.
Tamper	An on track machine that can (generally) lift and slue the track and simultaneously compact the ballast under the sleepers. Most machines employ some system to smooth out and average track faults, and apply predetermined lifts and slues to the track. The most advanced add some degree of computing power to further increase the effective measurement baseline (thus averaging the errors all the better). The machine's full title is more properly tamping and lining machine.*
Track circuit	An electrical or electronic device using the rails in an electric circuit that detects the absence of a train on a defined section of line.
Track geometry recording train	A specially equipped train that automatically measures and stores track geometry information for the lines that it runs over.
Track Maintenance Engineer	The Network Rail manager responsible for the delivery of track maintenance, and the line management of the Track Section Managers, within a defined area.
Track Section Manager	The local Network Rail manager directly responsible for managing teams of track maintenance staff.
Track twist	A rapid change in the level of the two rails relative to one another. Twist is calculated by measuring the level between the rails at two points a short distance apart (usually 3 metres), and then expressing the difference as a 1 in x gradient over the interval.
Up Sunderland	The name in the report given to the line used by trains travelling in the direction towards Sunderland and away from Newcastle.
Vehicle Inspection and Brake Test maintenance examination	A periodic (often annual) maintenance activity to ensure that a rail vehicle is in a serviceable condition and its brakes are functional.
VAMPIRE	Vehicle Dynamic Modelling Package in a Railway Environment. Trade name for a dynamic modelling system for rail vehicles which allows a virtual model of any rail vehicle to be run over real measured track geometry. Produced by Delta Rail (formerly AEA Technology).*

Voids	The spaces under sleepers or bearers in the packing area, often caused by inadequate packing or differential settlement between sleepers. It is voiding that is responsible for dynamic track faults, such as twist faults, that appear or worsen when the track is loaded.*
Wet bed	An area of ballast, usually between sleepers, contaminated with mud.
Wheelset	Two rail wheels mounted on their joining axle.
Workstation	A development of the signal box panel, the signaller is provided with a display of the signal box diagram on a series of VDUs, and a trackball and keyboard to operate the signalling functions.*

Appendix C - Sources of Evidence

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

- Information provided by witnesses and in staff reports;
- Information taken from the train's on-train data recorder;
- Closed circuit television (CCTV) recordings taken from Network Rail's track geometry recording trains and from Tyne and Wear Metro stations;
- Site photographs and measurements;
- Track geometry recording data recorded by Network Rail's infrastructure measuring trains;
- Network Rail's records for track inspection and maintenance activities;
- Information related to Network Rail's track renewals carried out in the Heworth area in 2012 and 2013;
- Information related to Network Rail's drainage improvements carried out in the Heworth area in 2013 and 2014;
- Network Rail's control logs;
- Freightliner's maintenance records for wagon 10769;
- Measurements recorded during an examination of wagon 10769's suspension components;
- Freightliner's maintenance instructions for the PCA wagon fleet and maintenance manuals for the suspension;
- Design information for the PCA wagon including its dimensions and suspension components;
- A computer simulation commissioned by the RAIB which enabled analysis of the interaction between the train and the track;
- Records for tests carried out during the 1990s on the PCA wagon including static and ride performance test reports;
- A metallurgical examination commissioned by the RAIB which enabled analysis of the worn damper pad's material properties; and
- A review of previous RAIB investigations that had relevance to this accident.

Appendix D - Dynamic modelling of the wagon's ride performance

D1 A vehicle model for the PCA wagon was created using an existing vehicle model with a Gloucester pedestal suspension as its starting point. Design information for the PCA wagon and measurements from the wagon that derailed were used to create a new vehicle model. The new vehicle model was validated against results recorded when PCA wagons underwent ride performance tests during the 1990s. The results from the model and test reports were well matched.

D2 The vehicle model represented a PCA wagon in its tare condition. Variants of the vehicle model were created to represent the suspension on the leading right-hand corner with 50% damping, 25% damping, no damping and finally with no damping plus an 8 mm gap between the pedestal and saddle friction liner plates. The suspensions on the other three corners were modelled as correctly damped. As the work was to understand the relative effect of a loss of damping within the pedestal suspension on one corner, it was not necessary for the vehicle models to account for worn components or any variations in damping in the other three corners.

D3 To model the derailment conditions, a track model was created using track geometry data recorded by the PLPR train that ran over the Down Sunderland line on 11 October 2014. This data set contained a dynamic measurement of the vertical track geometry, including the cyclic top defect.

D4 Figure 11 shows that when the vehicle model with a correctly damped suspension was run over the track model, the simulation predicted the leading left-hand wheel was fully unloaded over a distance of 0.5 metres and lifted off the rail by 1.4 mm. As the amount of damping on the leading right-hand suspension was reduced, the predicted distance over which the leading left-hand wheel was fully unloaded was longer and the amount the wheel was lifted increased. On the vehicle model with no damping and a gap between the friction liner plates, the leading left-hand wheel was fully unloaded for 3.1 m and lifted by 17 mm.

D5 None of the simulations predicted a derailment. Although the wheel was predicted to be fully unloaded and lifted off the rail, the amount of lateral force was small and not sustained for a long enough period for the flange to climb onto the rail head. Further simulations showed that by making relatively small changes, such as increasing the amount of friction between the wheel and the rail or changing the angle that the wheel was in contact with the rail, a small additional sustained lateral force was generated. This increase in lateral force was enough for the simulation to then predict the leading left-hand wheel climbing onto the rail head followed by derailment.

D6 Such a small amount of lateral force could also arise through other factors not included in the vehicle models such as the wagon's centre of gravity being laterally offset or differences in the amount of damping in the suspensions on the other corners of the wagon. Typical values for the amount of suspension damping were used in the vehicle models as actual values at each corner could not be measured due to the damage sustained when the wagon ran derailed. While this meant the simulations did not predict a derailment, they achieved their objective of showing what effect the loss of suspension damping on one corner of a PCA wagon has on its ride performance.

D7 A further series of simulations were carried out to understand how the risk of derailment changed in response to speed. These simulations ran the vehicle models over the track model at speeds of 30 mph (48 km/h) to 60 mph (97 km/h) in 5 mph (8 km/h) increments. Tables D1 and D2 show the results of these simulations in terms of predicted amounts of wheel unloading and wheel lift.

Speed **Vehicle model**	**30 mph (48 km/h)**	**35 mph (56 km/h)**	**40 mph (64 km/h)**	**45 mph (72 km/h)**	**50 mph (80 km/h)**	**55 mph (89 km/h)**	**60 mph (97 km/h)**
100% damping	45%	48%	52%	77%	100%	100%	100%
50% damping	47%	51%	74%	86%	100%	100%	100%
25% damping	48%	66%	75%	100%	100%	100%	100%
No damping	58%	71%	81%	100%	100%	100%	100%
No damping plus 8 mm gap	58%	76%	100%	100%	100%	100%	68%

Table D1: Simulation results showing predicted amounts of wheel unloading for the leading left-hand wheel at a range of speeds

Speed **Vehicle model**	**30 mph (48 km/h)**	**35 mph (56 km/h)**	**40 mph (64 km/h)**	**45 mph (72 km/h)**	**50 mph (80 km/h)**	**55 mph (89 km/h)**	**60 mph (97 km/h)**
100% damping	0.0	0.0	0.0	0.0	0.0	3.7	0.4
50% damping	0.0	0.0	0.0	0.0	5.5	10.0	4.9
25% damping	0.0	0.0	0.0	1.6	7.1	7.3	0.3
No damping	0.0	0.0	0.0	4.9	8.6	9.3	0.1
No damping plus 8 mm gap	0.0	0.0	3.2	11.4	16.9	13.3	0.0

Table D2: Simulation results showing predicted amounts of wheel lift in mm for the leading left-hand wheel at a range of speeds

D8 As in the case of the previous simulations (paragraphs D5 to D7), none of these simulations predicted a derailment because the lateral force was too small. However, they did identify the cases where the risk of derailment was highest, ie those cases with the highest predicted levels of wheel unloading and wheel lift.

D9 The results in table D1 show that wheel unloading generally increases with vehicle speed and a reduction in the amount of suspension damping. The leading left-hand wheel was predicted to be fully unloaded for all the vehicle models at a speed of 50 mph (80 km/h) or greater. By reducing the amount of damping in the suspension, it is less able to control the response of the wheelset, leading to a greater amount of movement and an increased the propensity for the wheels to be unloaded. In the 'no damping plus an 8 mm gap' simulations, the saddle was free to move within the pedestal with no damping at all. However, for the 'no damping' simulations, there was a minimal amount of damping in the leading right-hand suspension, which arose from the saddle being pushed against the pedestal by the forces generated when the wheelset went around the curve at Heworth.

D10 Table D2 shows that the greatest amount of wheel lift, 16.9 mm, is predicted at a speed of 50 mph (80 km/h) for the suspension with no damping and an 8 mm gap. This case matches both the derailed wagon's condition and the recorded speed at the time of derailment. It also occurs at the same place in the track model where wagon 10769 had derailed at Heworth. It is most likely that the peak amount of wheel lift occurs at 50 mph (80 km/h) due to the rises and falls in the vertical track geometry being in phase with the vertical movement of the wagon's leading wheelset as its suspension responds to each dip.

Appendix E - Cyclic top measurement, actions and repair

E1 The reports for cyclic top defects provide a value that is calculated by an algorithm. The data for the vertical geometry of each rail is filtered at defined wavelengths and then input into this algorithm. The chosen wavelengths are based on divisions of 18.3 metres which equates to a 60 foot length of rail[10]. For each wavelength, the algorithm looks for a peak in the filtered data which is above a defined threshold. It then looks for the next peak above the threshold within a distance which is set by the particular wavelength. If another peak is found, the algorithm adds the peak values together. This process continues until no further peaks above the threshold are found within the distance for that particular wavelength. The algorithm then outputs summed peak values (in mm) for the left rail, right rail and both rails, along with the number of peaks found and the start and end locations of the defect.

E2 The cyclic top value is then used by Network Rail to determine what action needs to be taken by the local track maintenance team. The intervention limits and actions to be taken are stated in NR/TRK/L2/001/mod11 and reproduced in table E1. If the cyclic top value requires an immediate action, this will be the imposition of a 30 mph (48 km/h) emergency speed restriction. Other cyclic top values which are less severe require the imposition of a 30 mph (48 km/h) emergency speed restriction within 36 hours. The choice of a 30 mph (48 km/h) speed restriction is based on it being low enough for all types of vehicle to pass over the cyclic top track defect safely, including two-axle wagons, which historically were known to be susceptible to derailment on cyclic top track defects.

E3 Network Rail also uses the data captured by its track geometry recording trains to understand the overall quality of its track with respect to its vertical profile and alignment. Values for each are expressed as a SD value for every eighth of a mile. Network Rail specifies maximum and target SD values in standard NR/L2/TRK/001/mod11.

E4 Network Rail uses the data from the last ten track geometry recording runs to produce a chart which shows how the SD values have changed over time. Each SD value on the chart is colour coded according to which band it falls into to assist with the identification of trends. There are five bands which are good, satisfactory, poor, very poor and super-red. The super-red band represents an eighth of a mile section whose SD falls in the maximum band, ie the overall quality of its vertical profile or alignment has deteriorated to the point where it now exceeds the upper limit of the very poor band. NR/L2/TRK/001/mod11 defines the actions that the responsible Track Section Manager needs to take when a super-red SD is reported, such as carrying out additional inspections. This can also include the imposition of a speed restriction.

[10] Historically jointed track was constructed using 60 foot (18.288 metres) lengths of rail and dips at the joints between the sections of rail would lead to the formation of cyclic top track defects. Therefore the wavelengths analysed for cyclic top track defects are all divisions of 18.288 metres. These are 18.288 metres (18.288÷1), 12.192 metres (18.288÷1.5), 9.144 metres (18.288÷2), 6.096 metres (18.288÷3) and 4.572 metres (18.288÷4).

Cyclic top category	Permitted speed	Intervention limits for cyclic top values	Action required
Immediate	Above 30 mph (48 km/h)	30 mm or greater on one rail or 50 mm or greater on both rails	Immediately impose a 30 mph (48 km/h) emergency speed restriction and correct the defect within 36 hours
A	Above 30 mph (48 km/h)	26 mm to less than 30 mm on one rail or 46 mm to less than 50 mm on both rails	Impose a 30 mph (48 km/h) emergency speed restriction within 36 hours and correct the defect within 14 days
B	Above 30 mph (48 km/h)	23 mm to less than 26 mm on one rail or 43 mm to less than 46 mm on both rails	Impose a 30 mph (48 km/h) emergency speed restriction within 36 hours and correct the defect within 30 days
C	Above 30 mph (48 km/h)	20 mm to less than 23 mm on one rail or 40 mm to less than 43 mm on both rails	Correct the defect within 60 days
D	All speeds	18 mm to less than 20mm on one rail or 38 mm to less than 40mm on both rails	No prescribed timescale for action to be taken. Correct the defect during planned maintenance.

Table E1: Intervention levels for cyclic top track defects in Network Rail standard NR/TRK/L2/001/mod11

E5 For track with poor vertical track geometry, including discrete top or cyclic top track defects, a standard manual repair method used by track maintenance teams is known as ‘measured shovel packing’. This method involves lifting the track with jacks and putting a measured amount of small stones or chippings under the sleepers in the dip. The sleepers are then supported by this new material thereby removing the dip. However, this type of repair takes longer than other methods (described in the next paragraph) because any voids need to be measured first. To do this, void meters must be installed. These devices measure the vertical deflection of the track under a passing train, and hence the size of the voids under the sleepers. The void meter readings allow the amount of stone needed under each sleeper to be determined.

E6 'Shovel packing' is a quicker way of lifting and packing the track to improve the vertical geometry. This method entails the track maintenance team lifting the track with jacks and then using shovels to put new ballast under the sleepers. Alternatively, the track maintenance team can pack the existing ballast under the track by lifting the track and then using mechanical tools to vibrate the existing ballast to consolidate it under the sleeper. Neither of these repair methods will effect a long lasting repair as the ballast cannot be sufficiently compacted under the sleeper to prevent it from being pushed down over time under the weight of passing trains. However, these methods can be used to maintain the track geometry until a longer lasting repair can be planned and made.

E7 Network Rail issues guidance to staff on the different methods of lifting and packing in Track Work Information Sheets[11]. These include the information that shovel packing is the least preferred option. The same information sheets state that lifting and packing with mechanical tools is the preferred method where the ballast is in good condition, but is unsuitable for use where the ballast is contaminated by dust or mud (which was the case at the point of derailment).

E8 On-track machines are used to make a longer lasting repair. Network Rail can use an on-track machine called a stoneblower to correct top or cyclic top track defects. The stoneblower lifts the track and injects a measured amount of stone chippings under the sleeper to support it. The sleepers are then lowered onto the chippings, which consolidate under passing trains. If a stoneblower cannot be used, the only other option available to Network Rail for improving the track's vertical geometry is to use an on-track machine called a tamper. A tamper lifts the track and at the same time compacts the existing ballast beneath the sleepers using tines, which are spade ended tools. The tines are pushed down into the ballast and vibrated, which shakes the ballast and compacts it under the sleeper.

E9 If the manual and on-track machine repairs prove to be ineffective, and the track condition continues to deteriorate, the Track Maintenance Engineer can seek investment to carry out major works such as a track renewal. The Track Maintenance Engineer should write a *problem statement* that describes the issue and what renewal work is needed. This will then be entered into TRS.

E10 Once on TRS, the problem statement passes to a team who work for the RAM (track). The RAM (track) team will review the problem statement, visit the site and if accepted, include the proposed work in the track renewal programme. The renewal will then be progressed, with its timescale for delivery dependent on how urgent the RAM (track) team considers it to be in comparison to all of the other planned track renewal work.

[11] These are listed in Network Rail guidance note NR/GN/TRK/7001.

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