Rail Accident Investigation Branch

Rail Accident Report

Derailment at Liverpool Street station, London
23 January 2013

Report 27/2014
December 2014

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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Derailment at Liverpool Street station, London 23 January 2013

Contents

Summary

Shortly after 10:00 hrs on Wednesday 23 January 2013, train 1P18, the 10:00 hrs Greater Anglia service from London Liverpool Street to Norwich, derailed 260 metres from London Liverpool Street. The train comprised nine coaches pushed by a locomotive, and had just left platform 13. A total of 17 wheelsets derailed on a tight curve and, as the train proceeded, all the wheelsets were guided back onto the correct rail within a distance of 40 metres.

The driver was unaware of any problem until the senior conductor told him that passengers had reported a rough ride and the signaller advised him that the signalling system had identified a problem at a set of points used by the train when leaving Liverpool Street. The driver then stopped and examined his train at Shenfield, but saw nothing unusual. No one appreciated that there had been a derailment until the train was examined by a specialist inspector when it arrived at Norwich and, at about the same time, a signal maintenance team found track damage close to Liverpool Street station.

The train derailed on the curve because the track fixings had deteriorated over a period of time. This tight curve and other non-standard trackwork at Liverpool Street should have triggered consideration of mitigation measures to deal with the associated enhanced derailment risk. The investigation found that no consideration had been given to these enhanced risks because the maintenance management staff did not have the knowledge necessary to appreciate the need for, and to undertake, this activity. This lack of knowledge had not been appreciated by more senior staff. The Network Rail procedures for establishing a track inspection and maintenance regime for non-standard track did not require the regime to be independently checked.

The RAIB has identified six learning points and three recommendations. One learning point relates to effective communication between train and incident controllers when dealing with events which could be associated with urgent safety issues. A second learning point restates the relevance of Network Rail's existing requirements for verifying maintenance management staff competencies relevant to risk assessing track assets. Three learning points refer to the need for a complete record of assets requiring maintenance, the importance of looking for signs of rail movement when inspecting track and the correct use of data obtained from a commonly used track geometry measurement device (an Amber trolley). The final learning point refers to the need for proper archiving of inspection records.

The three recommendations are all addressed to Network Rail. The first relates to providing assurance that suitable inspection regimes are established, recorded and validated for non-standard track assets. The second recommendation is intended to ensure assessment of management staff's safety critical track related competencies to ensure they have the necessary experience and knowledge to perform that role. The third recommendation seeks a review and, if necessary, improvement of the competency assessment processes applicable to managers with safety critical roles linked to the maintenance of assets other than track.

Introduction

Preface

1 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.

2 Accordingly, it is inappropriate that the RAIB's 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.

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

Key definitions

4 All dimensions in this report are given in metric units, except speeds and locations which are given in imperial units, in accordance with normal railway practice. Where appropriate the equivalent metric value is also given.

5 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.

The accident

Summary of the accident

6 Shortly after 10:00 hrs on Wednesday 23 January 2013, train reporting number 1P18, the 10:00 hrs Greater Anglia service from London Liverpool Street to Norwich, derailed 260 metres after departing from London Liverpool Street station. The train comprised nine coaches pushed by a locomotive, and had just left platform 13. A total of 17 *wheelsets* (19 wheels) had derailed on a sharply curved section of track within 2035B *points* on the approach to 2035C points (figures 1 and 2). 2035B points form part of a *switch diamond crossing* (paragraphs 61 and 62).

7 The driver was unaware of the derailment and continued to drive the train normally. All of the derailed wheels were guided back onto the correct rail within a distance of about 40 metres. The driver remained unaware of any problem until he was contacted by the on-board senior conductor. The senior conductor asked him to stop and examine the train at Shenfield because passengers had reported a rough ride. The driver was also given a similar request by the signaller in response to the signalling system identifying a problem at 2035C points. The driver stopped and examined his train at Shenfield, but he saw nothing unusual. The train then continued to its final destination before anyone appreciated that there had been a derailment.

8 In addition to minor damage to the train wheels, the *bogie* of one coach, parts of 2035C points and approximately 40 metres of track were damaged. Significant disruption to services using Liverpool Street station continued until 05:45 hrs the following morning.

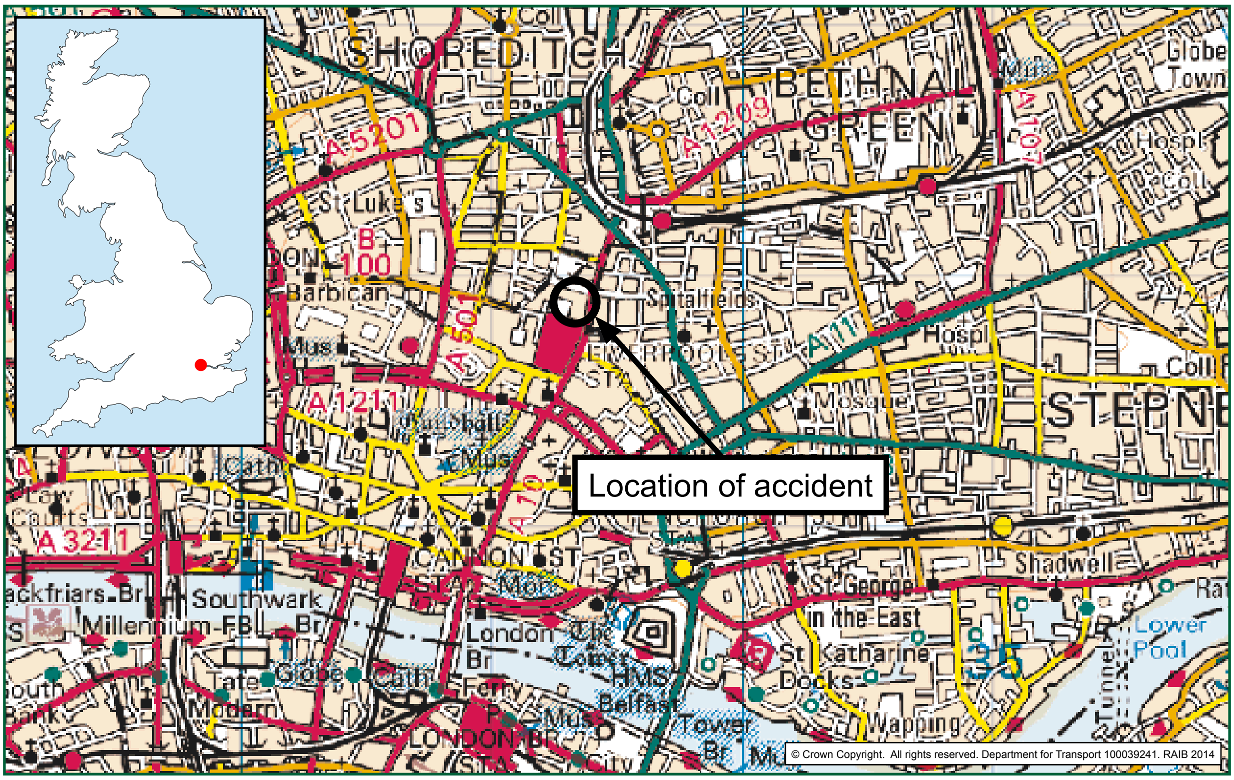

Figure 1: Extract from Ordnance Survey map showing location of accident

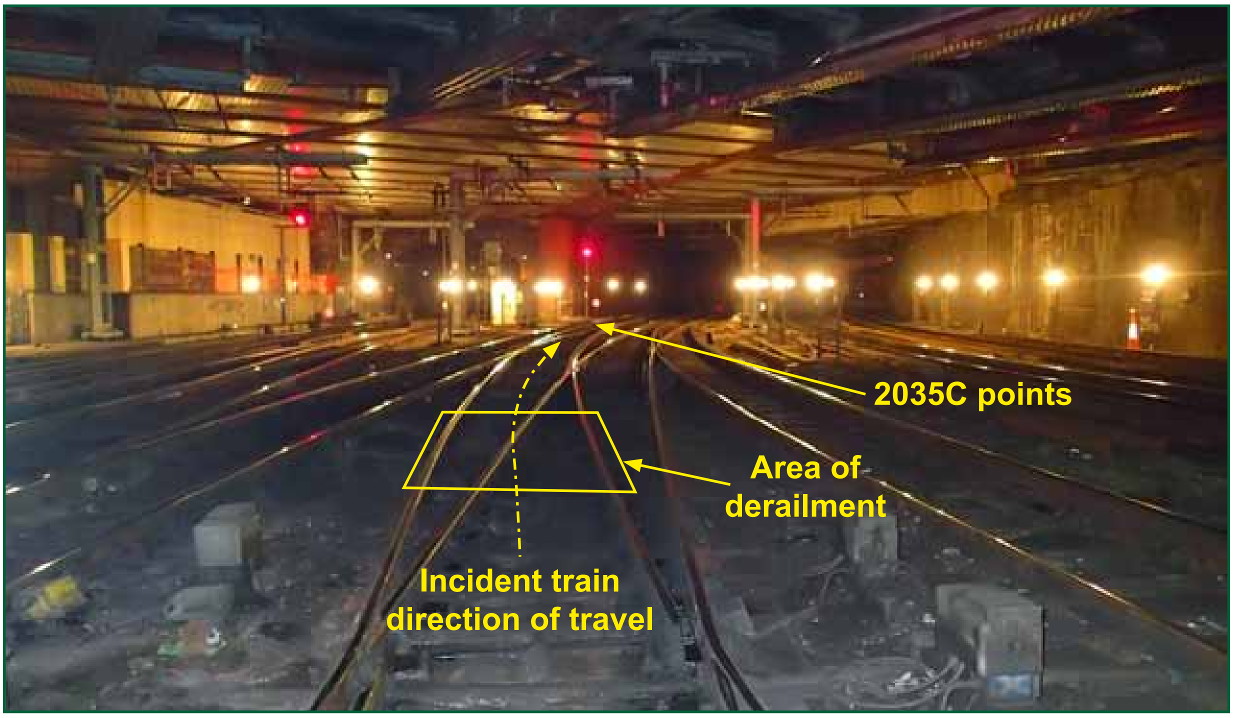

Figure 2: Derailment site showing path of train 1P18 (2035B points in centre of image)

Context

Location

9 Liverpool Street station is the London terminus for trains serving East Anglia, local services to north-east London and express services to Stansted Airport. A complex junction just outside the station routes trains between the three pairs of tracks approaching the station and the eighteen terminal platforms (figure 3). The junction consists of many sets of points linked with short sections of *plain track*. The maximum permitted speed for trains using this junction is 15 mph (24 km/h).

10 Signalling at Liverpool Street is by *track circuit block* and *colour light signals* controlled from Liverpool Street *Integrated Electronic Control Centre* (IECC).

11 Operating incidents are managed by Network Rail and Greater Anglia staff located in the Anglia *Integrated Control Centre* (AICC).

Organisations involved

12 Network Rail owns and maintains the track and signalling which is operated as part of its *Anglia Route*.

13 Abellio Greater Anglia Ltd (referred to as Greater Anglia in this report) operated the train which derailed, and employed both its driver and senior conductor. It also operated an empty train which passed over the derailment site shortly after the accident.

14 Greater Anglia and Network Rail's Anglia Route freely co-operated with the investigation. There were some delays in obtaining information from Network Rail national centre staff due to their workload.

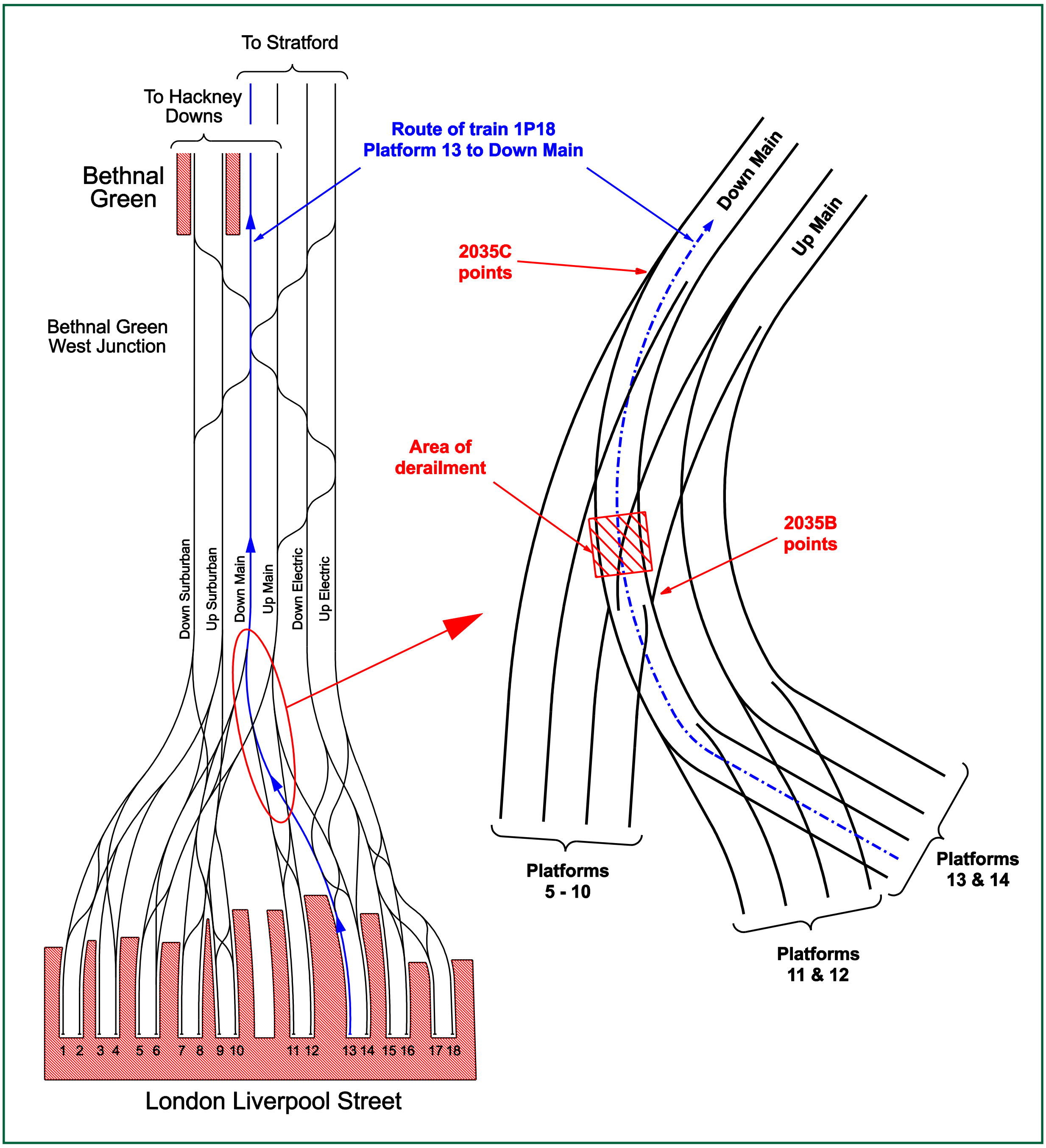

Figure 3: Liverpool Street station and detail of derailment area

Trains involved

15 The derailed train comprised an unpowered *driving van trailer* (DVT) at the front of the train and eight Mark 3 coaches propelled from the rear by a class 90 electric locomotive (figure 4). In this report, the DVT is designated vehicle 1 and the following coaches are designated vehicles 2 to 9 (figure 5).

16 A second train, an empty Class 321 *electric multiple unit*, reporting number 5V00, passed over the derailment site a short time after train 1P18, but did not derail.

17 Examinations of the train involved in the derailment by the RAIB and Greater Anglia found no evidence of pre-accident defects which could have contributed to the derailment.

Figure 4: A DVT leading a train formed of Mark 3 coaching stock. A class 90 locomotive is attached at the rear of the formation (not the train involved or the location of accident) (image courtesy of Kev Gregory/Railway Herald)

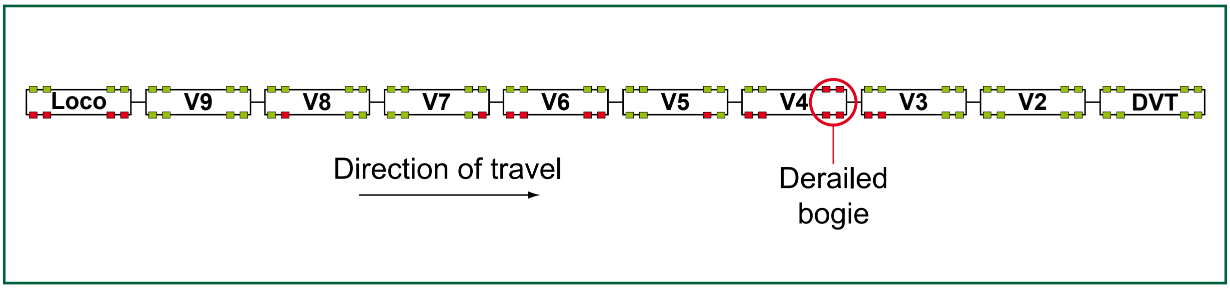

Figure 5: Train 1P18 (derailed wheels shown in red)

Staff involved

18 The key Network Rail maintenance staff involved with this investigation and their position within the organisational structure are shown in figure 6.

19 The route asset manager [track] (RAM[T]) had 33 years railway experience. This includes working in general track maintenance grades, eight years within a track design office and 13 years in senior track maintenance positions. He became RAM[T] in 2010.

20 The infrastructure maintenance delivery manager (IMDM) had 35 years experience in track engineering. His initial experience comprised six years track design and 16 years in track maintenance technical grades. He then became a track maintenance engineer in 1994 and held senior track maintenance positions through several business reorganisations. He was appointed Romford IMDM in October 2012.

21 The infrastructure maintenance engineer (IME) was an electrical engineer, who joined the railway in 2000. He worked in the fixed plant asset management organisation for eight years including a year as the area electrification and plant engineer on Wessex route. He became Romford IME in 2008.

22 The track maintenance engineer (TME) responsible for Liverpool Street joined the railway in 1984. He initially worked for a track renewal team before transferring to a track maintenance team and advancing through the grades to become TME in 2006. The TME is responsible for maintenance of track from Liverpool Street to Chelmsford.

23 The section manager [track] (SM[T]) joined the railway in 1984. He advanced through the track maintenance grades and reached the position of SM[T] in 1999. The SM[T] is in charge of the teams that undertake track maintenance at Liverpool Street.

24 The assistant track maintenance engineer (ATME) had over 30 years railway experience as a structures engineer before moving into the track maintenance discipline when he became ATME in 2012. The ATME provided the TME, the SM[T] and other track maintenance staff with technical support.

25 The *train services manager* employed by Greater Anglia and the *incident controller* employed by Network Rail were among the AICC staff who dealt with the derailment.

External circumstances

26 The derailment occurred where the track is sheltered from natural sunlight and rain by buildings built over the railway. The environment is dirty and dimly lit by artificial lighting.

Events during the accident

27 At approximately 10:00 hrs on Wednesday 23 January 2013, train 1P18 departed from platform 13. As the train was passing over 2035B points, and approaching 2035C points (figure 3), on a right-hand curved section of track about 260 metres from the platform end, 19 wheels of the train derailed (figure 5). Of these, 15 wheels were re-railed within 5 metres. The remaining four wheels were on a bogie which travelled in a derailed state for approximately 40 metres (around 6 seconds running time), before forcing its way through *(running through)* the converging rails of 2035C points and re-railing (paragraph 66)).

28 The senior conductor was towards the rear of train 1P18 and felt the train move in an unusual manner. The driver of the train was unaware of this rough ride and the damage incurred to 2035C points and continued to drive the train as normal.

29 As the train ran through 2035C points there was a *loss of detection* which was indicated on the *signaller's display* at the IECC. This indication is a warning to the signaller that the points are possibly not in a position which provides safe passage for trains. The signalling system then prevented the signaller from routing trains over the points. The *signalling shift manager* reported this to the Network Rail incident controller at the AICC who, at 10:05 hrs, requested attendance from the local signalling maintenance team.

30 As the senior conductor walked through the train she received reports from passengers of a rough ride and dust falling from the ceiling. At 10:13 hrs the senior conductor contacted the Greater Anglia train services manager at the AICC and expressed a concern that the train could have derailed. However, at the time of the call, the train was apparently running normally so they agreed that the senior conductor would ask the driver to make an unscheduled stop at Shenfield to examine the train.

31 The senior conductor contacted the driver and requested him to examine the train because of the rough ride report. Shortly after this, the driver was also contacted by the signaller who reported the loss of detection at 2035C points and also asked him to examine the train.

32 At approximately 10:30 hrs the train stopped with the left-hand side of the train alongside platform 3 at Shenfield. The driver contacted the signaller and arranged for train movements to be stopped on the adjacent track. After the signaller had confirmed that the train movements had been stopped, the driver climbed down on to the track and walked along the right-hand side of the train. The driver looked for loose or hanging objects which could have damaged the points. Although some of the right-hand wheels had marks caused by the derailment which would have been visible on close inspection, he was not looking for such damage as it was not yet appreciated that a derailment had occurred. At the rear of the train, the driver climbed on to the platform and started to walk back towards the front of the train. The driver continued looking for defects, but the platform restricted his view of the left-hand wheels.

33 After completing his examination, the driver reported back to the signaller that he had found no defects and considered the train safe to continue. The signaller gave the driver permission to proceed and the train continued to Norwich running at normal speeds of up to 100 mph (160 km/h). The Greater Anglia train service manager contacted one of Greater Anglia's *technical riding inspectors* and requested him to examine the train in more detail when the train arrived at Norwich.

34 Although they were located at adjacent workstations in the AICC, the Greater Anglia train services manager did not inform the Network Rail incident controller about the senior conductor's concerns that the train could have derailed, but did mention a rough ride.

35 At around 10:17 hrs, the signal maintenance team at Liverpool Street began investigating the continued loss of detection at 2035C points. A loss of detection can be caused by a number of mechanical misalignment or electrical faults. The derailment had not left any obvious marks in the immediate vicinity of the points, so the maintenance team had no reason to suspect that a derailment had occurred. Believing the fault to be with the point operating machine, they made routine maintenance adjustments to the machine mechanism. These adjustments re-established detection which allowed the signaller to route a train over the points.

36 At 10:35 hrs train 5V00, an empty class 321 electric multiple unit departed from platform 11. This was the first train to pass over the derailment site after the signal maintenance team had re-established detection. Train 5V00 passed over the derailment site without derailing or suffering damage, but as it passed over 2035C points, detection was again lost. This again prevented the signaller from routing trains over the points and the signal maintenance team resumed their investigations.

37 The signal maintenance team re-examined the point operating machine and, after not finding a fault, began looking for faults elsewhere. The signal maintenance team found that a crank forming part of the mechanical points drive mechanism had become detached from the track. This fault could not be fixed by the signal maintenance team so, at 12:31 hrs they requested the attendance of track maintenance staff.

38 While awaiting assistance from track maintenance staff, the signal maintenance team walked towards the station and observed significant damage to the track consistent with a derailment. This was reported to the AICC at about 12.47 hrs.

39 The incident controller had not appreciated that a derailment might have occurred until damage was reported to the AICC by the signal maintenance team. At approximately the same time, about 2 hours 45 minutes after the derailment, the technical riding inspector at Norwich reported to the AICC that he had found damage to wheels and bogie equipment consistent with a derailment.

40 The loss of detection at the damaged points prevented services using platforms 11 and 12; this trapped three empty trains at the station (each platform can accommodate more than one train). All other trains were forced to use alternative routes around the damaged points, causing disruption to services for the remainder of the day. Two of the six lines serving Liverpool Street remained closed until repairs were completed at 05:45 hrs on 24 January.

The investigation

Sources of evidence

41 The following sources of evidence were used:

- witness statements;
- the train's *on-train data recorder* data;
- data from the *Control Centre of the Future*;
- site photographs and measurements;
- Network Rail's records of track maintenance and inspections;
- examinations of the track on the day of the incident and when permanent repairs were carried out in November 2013; and
- a review of previous RAIB investigations that have relevance to this accident.

Investigation timing

42 The reasons for the derailment were established on the day of the accident in sufficient detail for Network Rail to begin implementation of the precautionary actions described in paragraphs 168 and 169. With the RAIB's agreement, Network Rail implemented emergency repairs shortly after the derailment to allow rapid reopening of the railway. These repairs included replacement of rail fixings damaged in the accident using components positioned so that they obscured, but did not destroy, the witness marks needed to gain the full understanding of the derailment mechanism described in this report. The RAIB decided to delay collection of this witness evidence until November 2013, the earliest date when it could be obtained without disrupting planned maintenance activities.

Key facts and analysis

Background information

Organisational Structure

43 Network Rail has structured its maintenance workforce into individual routes, each with their own route managing director (RMD) and associated management structure. The key Network Rail maintenance staff involved with this investigation and their positions within the organisational structure are shown in figure 6.

44 Below each RMD are several functions including two relating to infrastructure maintenance:

- **asset management,** to balance maintenance, renewal and enhancement activities for the best return on investment; and
- **maintenance delivery,** the workforce directly responsible for ensuring safety of the infrastructure and implementation of inspection and maintenance activities.

45 The asset management function is intended to use technical expertise, experience and records of asset deterioration to decide whether maintenance or renewal would best meet the safety and operational requirements of the railway. The team is split into specialist disciplines and covers the whole Anglia route. The track team responsible for Liverpool Street were based in offices near to Liverpool Street station, but have since moved to offices in Stratford.

46 The RAM[T] leads the Anglia route track asset management team responsible for the cost-effective management of track assets. The RAM[T] also provides technical assistance and mentoring to the route TMEs. He reports through the director of route asset management (DRAM) to the RMD.

47 The RAM[T] is also responsible for arranging the briefing of local maintenance staff about technical standards information originating from the Network Rail national centre in Milton Keynes.

48 The Anglia route maintenance teams are divided into geographical areas and specialist disciplines. For the track at London Liverpool Street the maintenance is undertaken by the maintenance delivery unit (MDU) based at Romford.

49 The Romford MDU is responsible for the infrastructure on the lines from London Fenchurch Street to Tilbury and Southend, and from Liverpool Street to Chelmsford on the main line to Norwich. The MDU works in accordance with Network Rail standards, Network Rail guidance and local knowledge to develop an inspection and maintenance regime. This is intended to ensure the safe operation of the railway and to meet the reliability and performance targets set by the RAM[T].

50 The MDU at Romford is led by the infrastructure maintenance delivery manager (IMDM) who is accountable[1] for safety of the line, and manages all maintenance disciplines, within this MDU.

[1] The accountable person typically ensures appropriate processes are in place. Tasks are actually undertaken by the responsible person, sometimes with assistance.

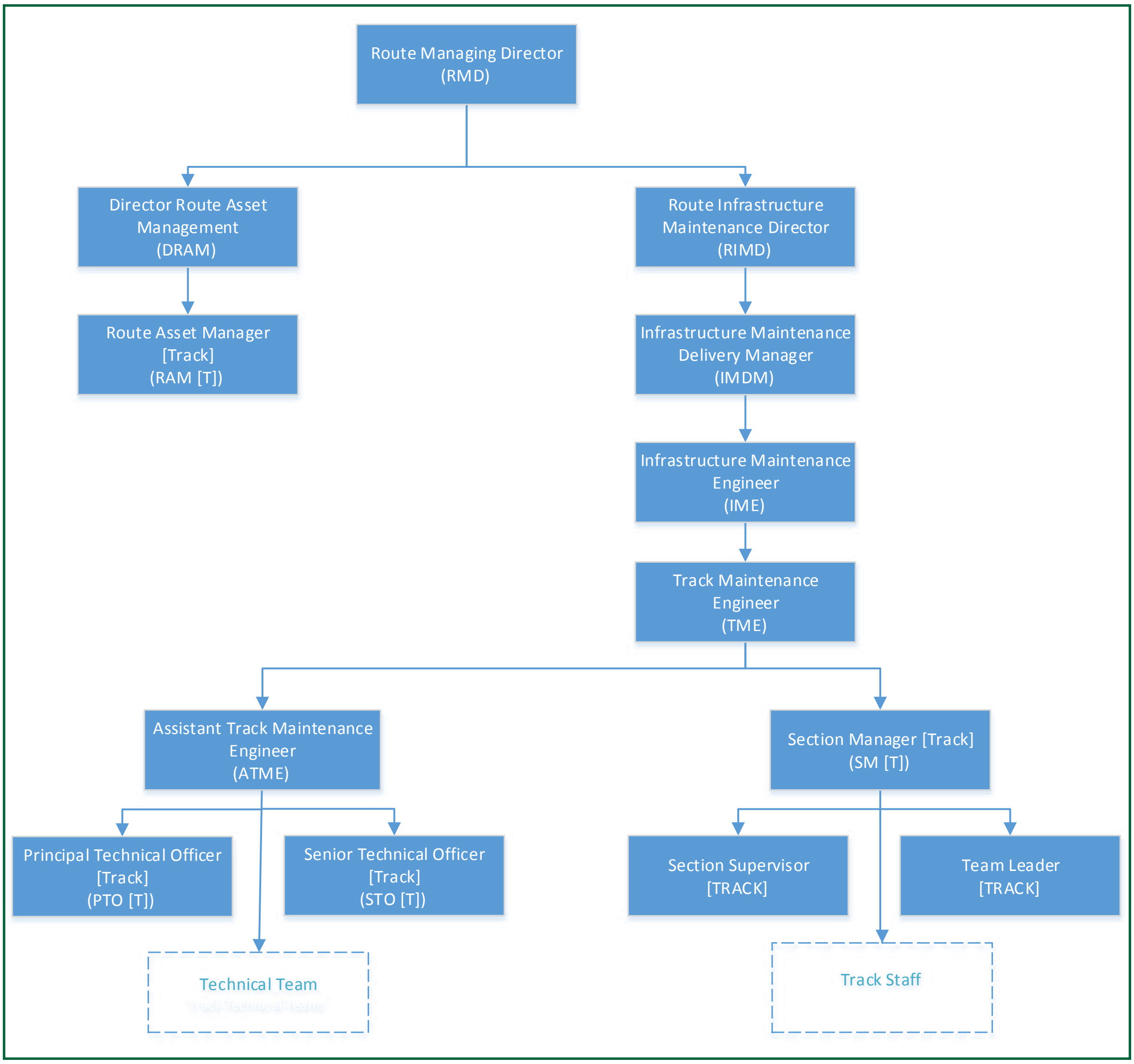

Figure 6: Organisation structure relevant to track maintenance

51 The Romford infrastructure maintenance engineer (IME) reports to the IMDM and is responsible for managing the staff who ensure the railway remains safe for operational use within the MDU area. His remit covers all engineering disciplines. Discipline-specific maintenance engineers report to him, including two track maintenance engineers. One of these covers the Fenchurch Street, Tilbury and Southend lines and the other covers the Liverpool Street to Chelmsford area, including the accident site.

52 Each TME is responsible for developing the inspection and maintenance regime for his geographical area and implementing this regime. The TME responsible for the Liverpool Street to Chelmsford area has support from an assistant track maintenance engineer (ATME) and two section managers [track] (SM[T]), each with their own support teams. The ATME provides input throughout the geographical area covered by the TME, but the same area is split geographically between the two SM[T]s.

53 The dates of appointment of key staff relevant to the investigation are shown in table 1. The relevance of these appointment dates is considered in paragraphs 121 to 150.

Position	Appointment
IMDM	October 2012
IME	2008
TME	2006
ATME	April 2012
SM[T]	1999

Table 1: Appointment dates of key staff at Romford MDU

Track Standards

54 Network Rail requires the inspection and maintenance of track to be in accordance with its standard NR/L2/TRK/001, 'Inspection and Maintenance of Permanent Way'. This standard prescribes the inspections, intervention limits and actions required to prevent derailments due to track defects and to optimise track performance, cost and asset life.

55 Network Rail standards are updated as necessary in response to the introduction of new technology, the application of new methodologies or in response to a previous incident requiring a new working practice. Where possible Network Rail issues the latest version ahead of the date when the company requires full compliance. This allows those people affected to prepare before full compliance is necessary.

56 NR/L2/TRK/001 had been updated several times and issue five was current at the time of the derailment. Issue six had been issued but, at the time of the derailment, compliance had not yet been mandated. The version history of NR/L2/TRK/001 is shown in table 2.

Issue number	Issue date	Compliance date
Initial Issue	August 2005	August 2005
Issue 2	October 2005	October 2005
Issue 3	26 August 2008	26 August 2008
Issue 4	05 December 2009	05 December 2009
Issue 5	02 June 2012	01 September 2012
Issue 6	01 December 2012	02 February 2013

Table 2: Issue dates of Network Rail standard NR/L2/TRK/001

57 Each standards update usually has an associated briefing pack which outlines the changes made from the previous issue. For issue 5 of NR/L2/TRK/001 the standard had been rewritten into a new format which was substantially different to previous formats. The differences between the versions of NR/L2/TRK/001 and how they are relevant to this investigation are covered in paragraphs 137 to 150.

58 Network Rail issues briefing updates, grouped by engineering discipline, which lists those standards that have been updated in the preceding period. It is the responsibility of all Network Rail staff to ensure they are aware of any updates to standards which apply to them by attending organised briefing sessions or by self-learning, and to implement those changes by the compliance date. Local managers maintain a record of staff attending briefings and follow up staff absence from briefings as necessary.

Identification of the immediate cause[2]

59 **The derailment occurred as train 1P18 negotiated the small radius curve at 2035B points because the outer rail fixings of the left-hand rail on the curve were unable to resist the lateral forces acting at the wheel/rail interface. The forces were sufficient to widen the track gauge such that the right-hand wheels on the trailing bogie of the third vehicle dropped between the rails.**

60 The following evidence supports this:

- Marks on the track.
- Marks on the wheels of train 1P18.
- Marks on the *sleepers* and damage to the *track fastenings* indicating lateral movement of the *track fixings*.
- Computer simulations of similar derailments which show that significant gauge spread forces are developed on small radius curves (paragraph 72).

61 When the RAIB examined the site it found evidence that the derailment had occurred on a section of movable *switch rail* that formed part of 2035B points.

62 These points, together with 2035A points, formed the switch diamond crossing illustrated in figure 7. A description of a switch diamond crossing is included at appendix D.

63 The derailment evidence comprised closely spaced marks on the right-hand rail indicating that all the derailed right-hand wheels of the train had dropped inside this rail approximately five metres beyond the *tip* of the moveable rail (figures 8 and 9). The RAIB has concluded from the wheel face (the outside face) damage on the train, and a lack of derailment marks elsewhere on the right-hand rail, that the 17 right-hand train wheels derailed in turn as they reached this location. At the point of initial derailment the track is on a right-hand curve and the left-hand wheels were running along a section of rail that should be fixed.

64 The first of the wheelsets exhibiting wheel face damage were on the *trailing bogie* of vehicle 3 (figure 5). Damage to the track fixings of the right-hand rail (figure 9) and the absence of damage on the left-hand wheels of this bogie show that these wheelsets continued with the right-hand wheels dropped inside the right-hand *running rail* while the left-hand wheels remained on the rail. Damage to the track fixings indicate that these wheels ran derailed for about 4.5 metres before encountering a *fishplate* forming part of a rail *joint.* As they struck the fishplate, the wheels were raised back up to rail level and guided back on to the running rail (figures 10 and 11).

[2] The condition, event or behaviour that directly resulted in the occurrence.

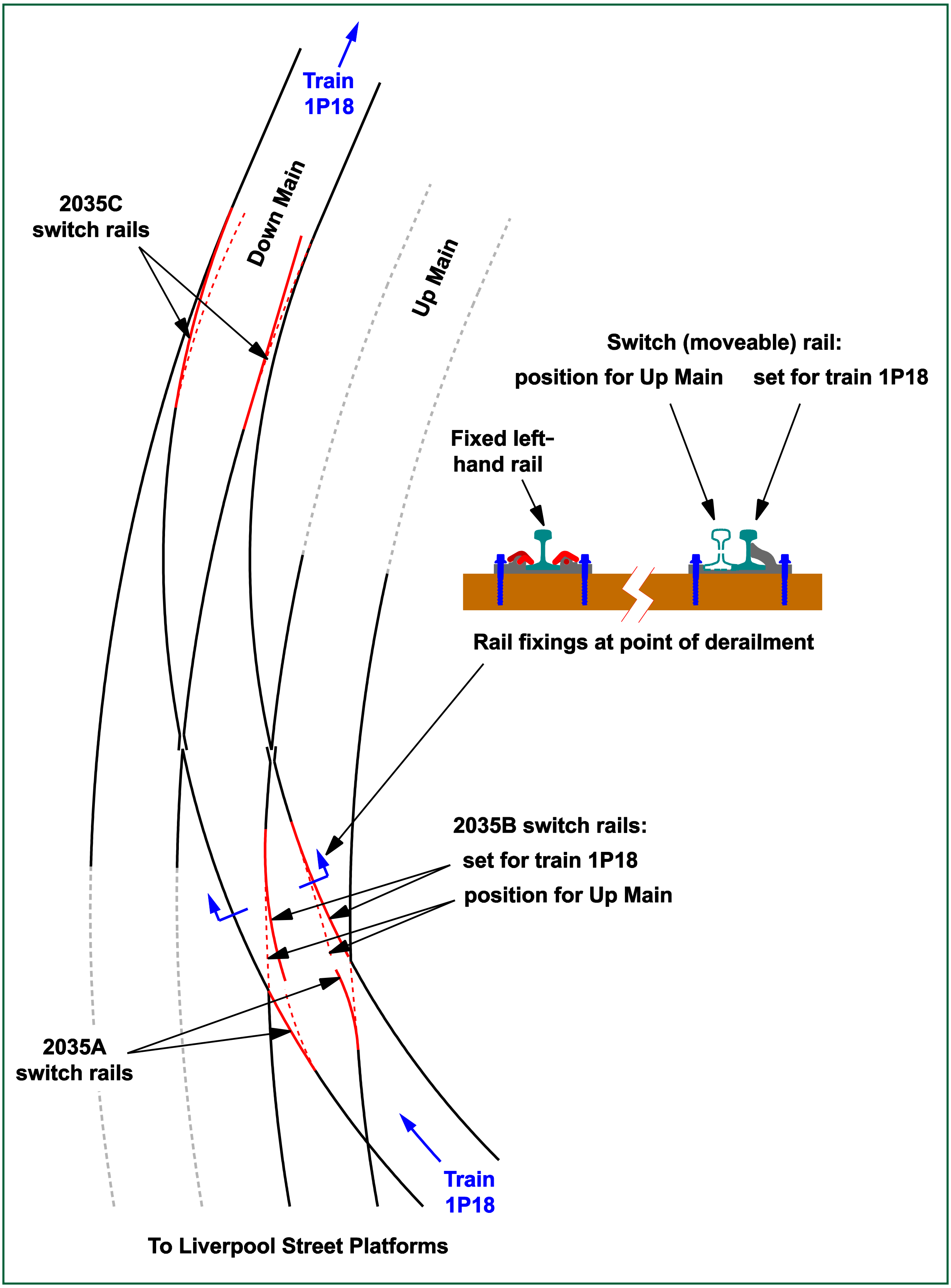

Figure 7: Track layout at incident site

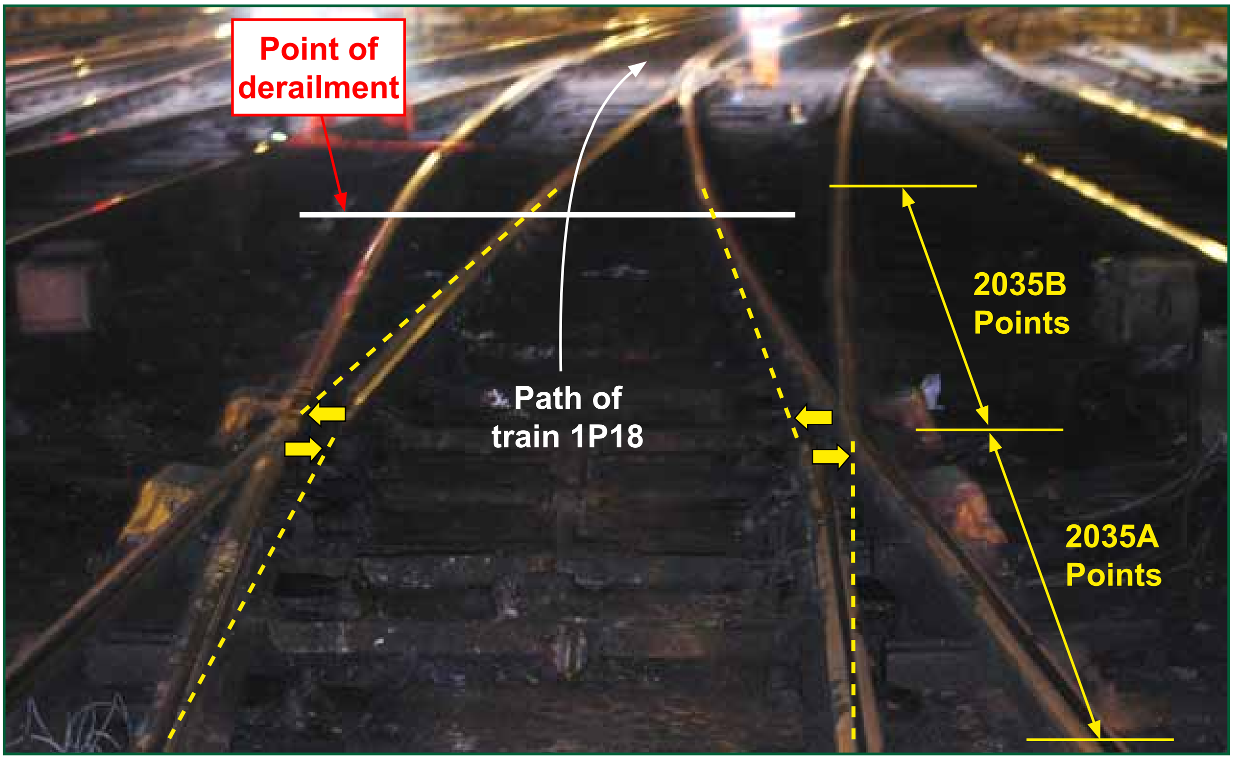

Figure 8: Incident site showing switch rails set for train 1P18 (alternative route shown in yellow)

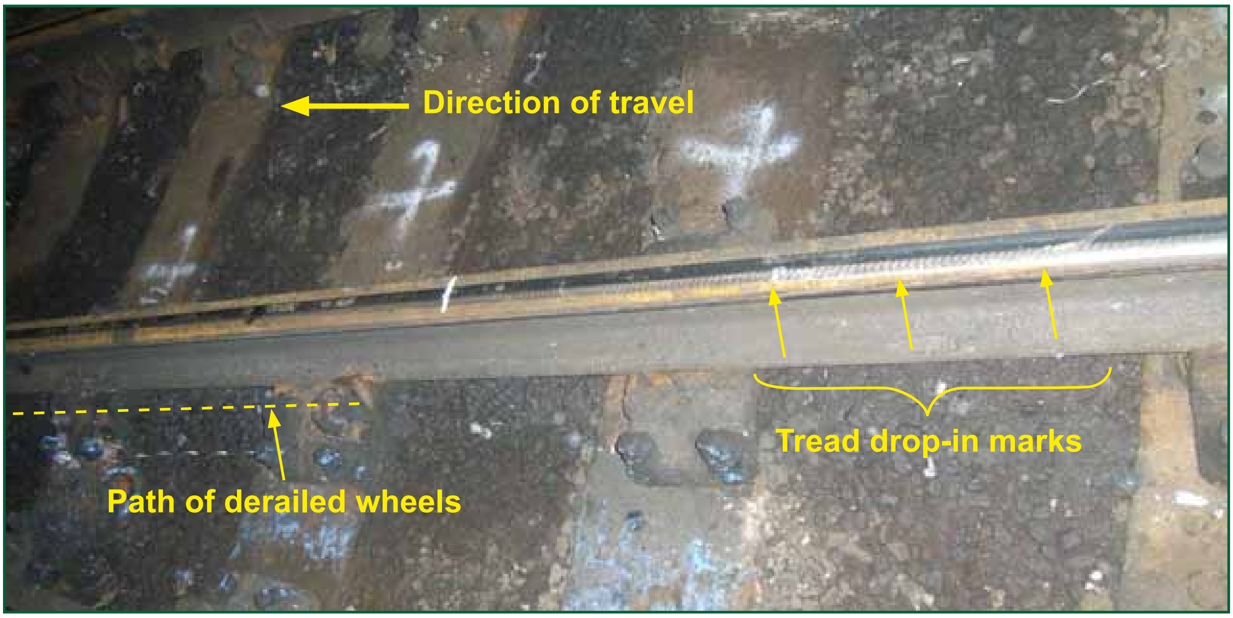

Figure 9: Wheel tread drop-in marks and damage caused by derailed wheels

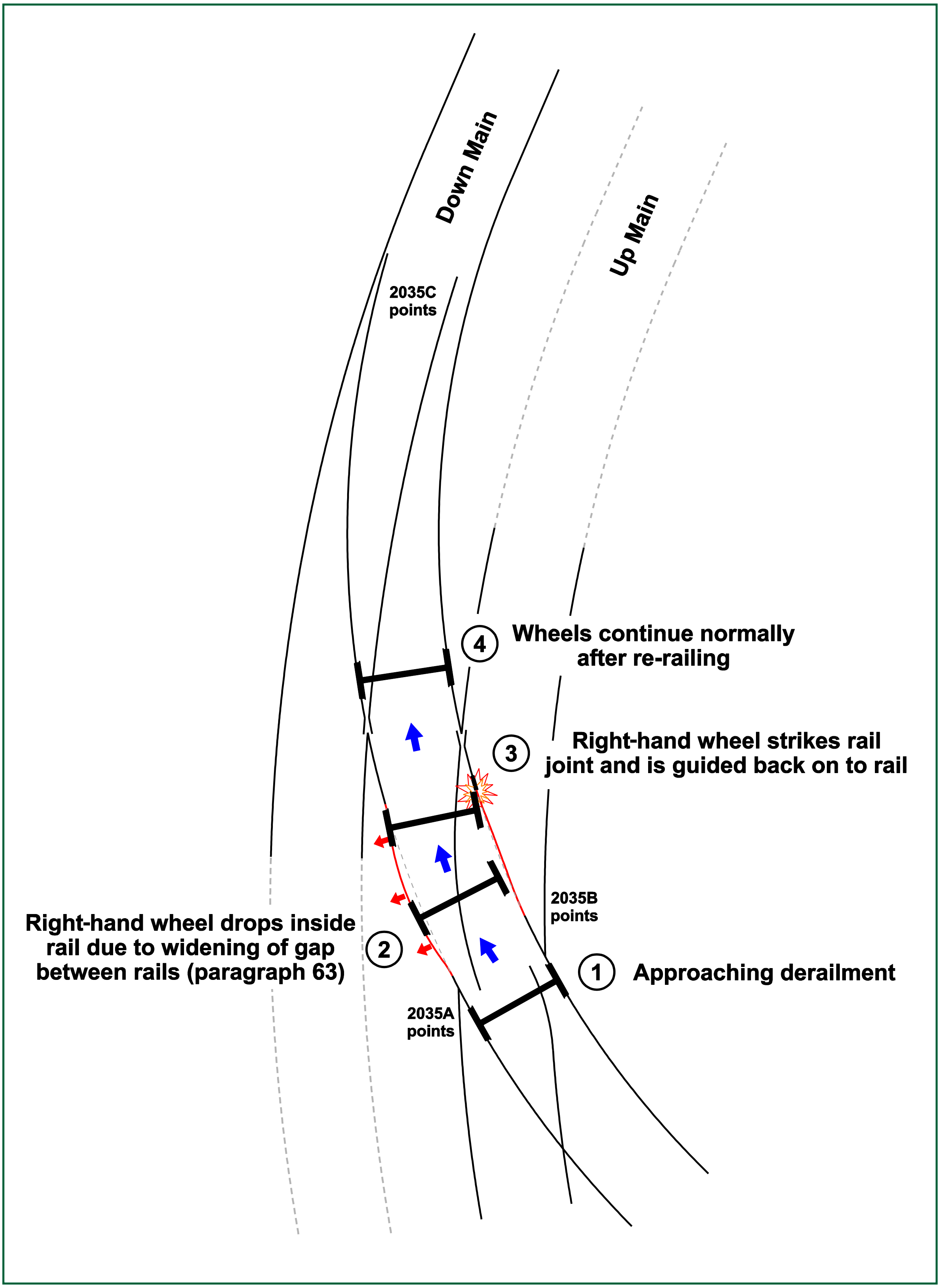

Figure 10: Derailment mechanism (excepting leading bogie of vehicle 4)

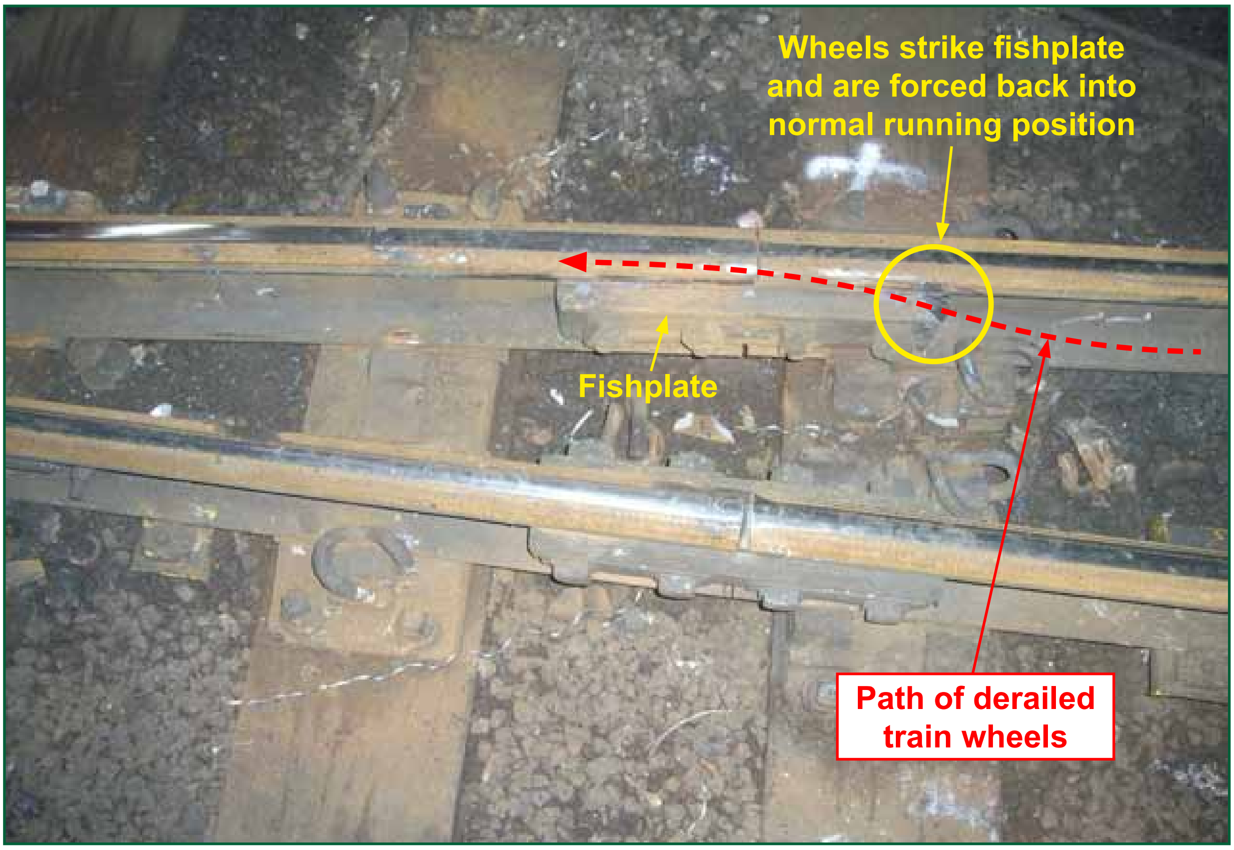

Figure 11: Rail joint which re-railed some wheels

65 Damage to all wheels on the *leading bogie* of vehicle 4 indicate that this bogie fully derailed. Rail head marks (paragraph 63) and marks on the right-hand wheel faces show that the right-hand wheels initially followed the same path as vehicle 3. However, instead of the right-hand wheels re-railing at the rail joint, the left-hand wheels climbed over the left-hand rail. This is evidenced by damage to the flanges of the left-hand wheels, marks left across the left-hand rail head and damage to the track fixings on the outside of the left-hand rail.

66 The extent of damage to track fixings shows that all wheels on this bogie then continued in a derailed state for approximately 40 metres until converging rails at 2035C points forced the wheels to run through the closed points and guided them back into a normal state on the running rails (figure 12).

67 On the remaining 13 wheelsets that derailed, damage was limited to the right-hand wheel face. This indicates that these wheelsets followed a similar derailment path to those of the trailing bogie on vehicle 3 (paragraph 64).

68 Scuff marks and depressions indicative of rail fixing movement were evident on the upper surface of sleepers near the point of derailment. The extent of these marks observed by the RAIB showed that the left-hand rail fixings had moved outwards, increasing the distance between the running rails by up to 35 mm. This rail was intended to remain in a fixed position but it was able to move as a consequence of deterioration of the rail fixing (paragraphs 82 to 84).

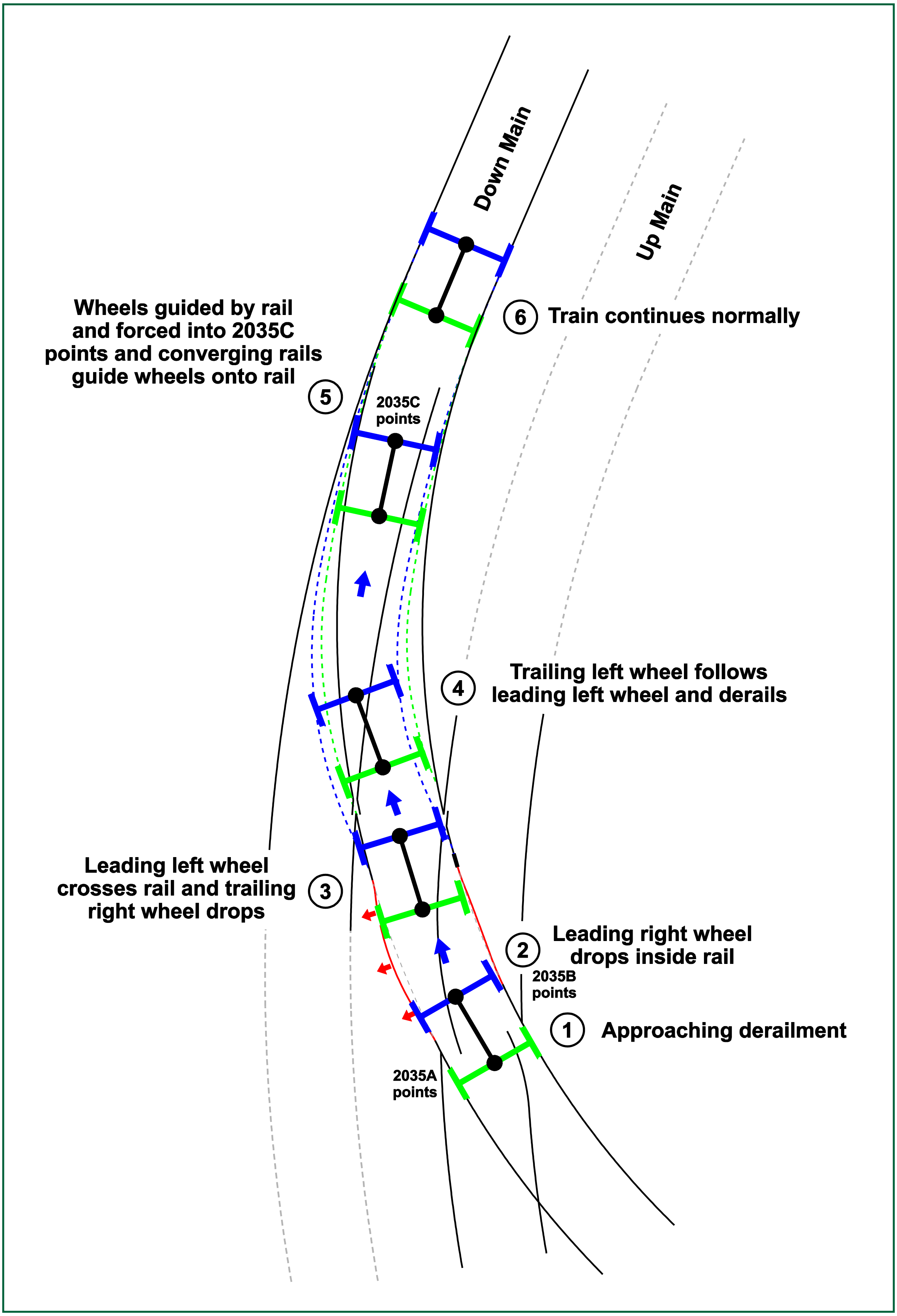

Figure 12: Derailment mechanism for vehicle 4 leading bogie

69 Conventional rolling stock, like the coaches of train 1P18, can generate large lateral forces at the wheel/rail interface when they negotiate small radius curves. This force will act to spread the rails apart if they are not fully restrained and evidence of gauge spread at this location is provided by scuffing marks (paragraph 68).

70 Although the track in the derailment area was tightly curved, with a radius of 125 metres, the inner (right-hand) rail was not equipped with a *check rail*. Had such a rail been provided, it would have been placed close to the right-hand rail (figure 13) and contacted the *back* of the right-hand wheels. This would have reduced the lateral forces applied to the left-hand (outer) rail and prevent the right-hand wheels dropping between the rails.

Figure 13: Typical check rail

71 Current Railway Group standard GC/RT5021 normally requires a check rail on curves less than 200 m radius. However, the standard reflects Network Rail's view that this is not viable on movable rails such as the right-hand rail at this site.

Identification of causal factors[3]

Behaviour of the track

72 The RAIB has investigated a number of derailments on small radius curves where widening has occurred due to the lateral forces exerted by the passage of trains. The RAIB investigation of the derailment at Liverpool Central underground station on 26 October 2005 (RAIB report number 14/2006), found that these lateral forces (gauge spreading forces) generally increase if the track gauge widens. The vehicle dynamic study commissioned by the RAIB as part of the Ordsall Lane Junction investigation (RAIB report number 07/2014) also found a similar gauge spreading force. In both these instances the forces combined with other factors and resulted in a different type of derailment from that at Liverpool Street.

[3] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

73 In the vicinity of the derailment, the RAIB found that the distance between the rails was wider than normal, and there were signs of deterioration allowing movement in the rail fixings intended to resist such movement. The RAIB has concluded that the following factors are the most likely explanation of how the rails became sufficiently separated for the right-hand wheels on vehicle 3 to drop inside the rails:

- **the wider than normal track gauge on the curve** with no trains present (*static gauge*) (paragraphs 75 to 80);
- **the degraded condition of the rail fixings** in the vicinity of the derailment, which reduced the strength of the connection between the rails and sleepers, making it easier for the rails to move apart as train 1P18 passed over (paragraphs 81 to 97); and
- **an increasing gauge spreading force** due to the combined effects of excessive static gauge and rail movement due to the degraded rail fixings causing additional deflection of the left-hand rail under the passage of train 1P18 (paragraphs 98 to 101).

74 The RAIB did not observe any defect with train 1P18 which would indicate that it was significantly more at risk of derailment by gauge spread than any other trains that were regularly routed over the curve. It is therefore likely that similar gauge spreading forces were being generated by trains preceding the passage of 1P18, and that these forces were themselves the cause of the deteriorating condition of the both the track gauge and the rail fixings.

Wider than normal static track gauge

75 The wide static track gauge, which had developed on the curve between 2035B and 2035C points, reduced the margin that was available for the rails to safely deflect when train 1P18 passed over. This was a causal factor.

76 Most rails at Liverpool Street, except switch rails, are fixed to wooden sleepers using a retaining system consisting of a *baseplate* which is screwed to the sleeper using *chairscrews* and *spring clips* which clamp the *foot* of the rail to the baseplate (figure 14). This type of fixing is intended to resist the forces imposed on the rail by train movement.

77 To ensure the safe passage of trains the distance between the rails (gauge) must be maintained to ensure adequate support for the train wheelsets. This distance can be increased both by design and by the normal deterioration of track in service. As an increased gauge can increase the risk of derailment, Network Rail standard NR/L2/TRK/001 defines the limits at which intervention should take place to maintain a suitable gauge and associated safety margin.

78 The original track design drawings showed an increase in the standard track gauge of 1435 mm to 1441 mm at the derailment site. This increase is normal practice and is intended to ease the passage of trains negotiating small radius curves.

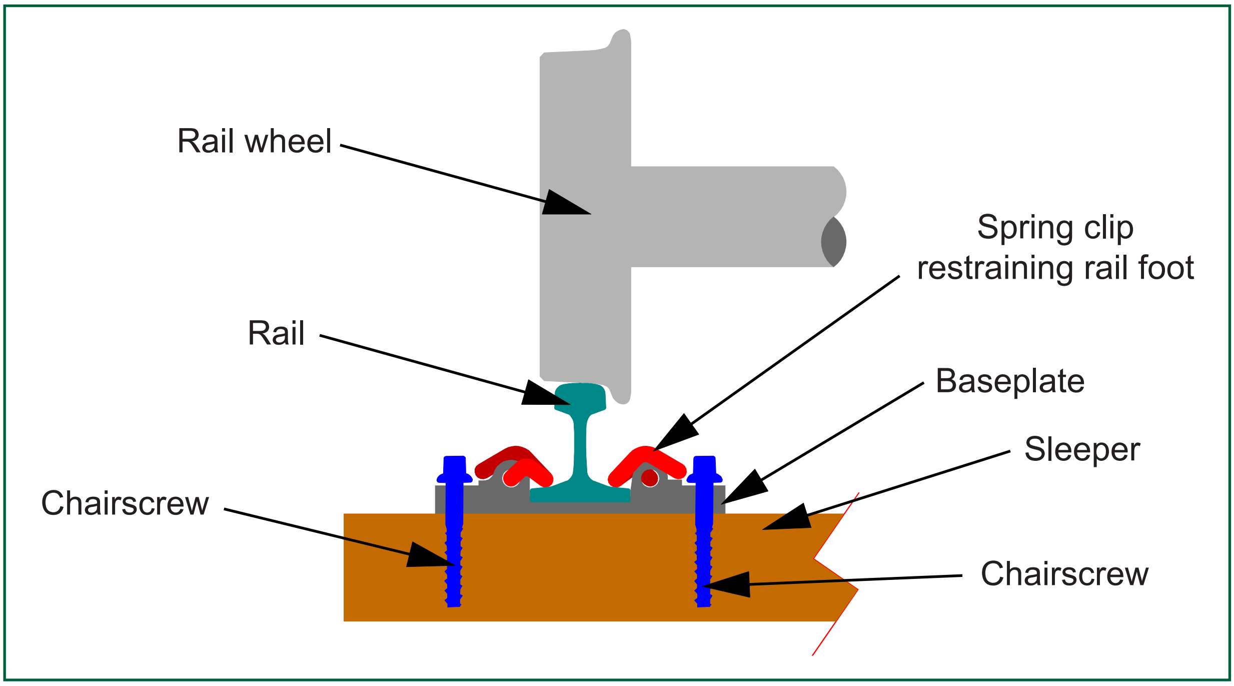

Figure 14: Rail fixing system

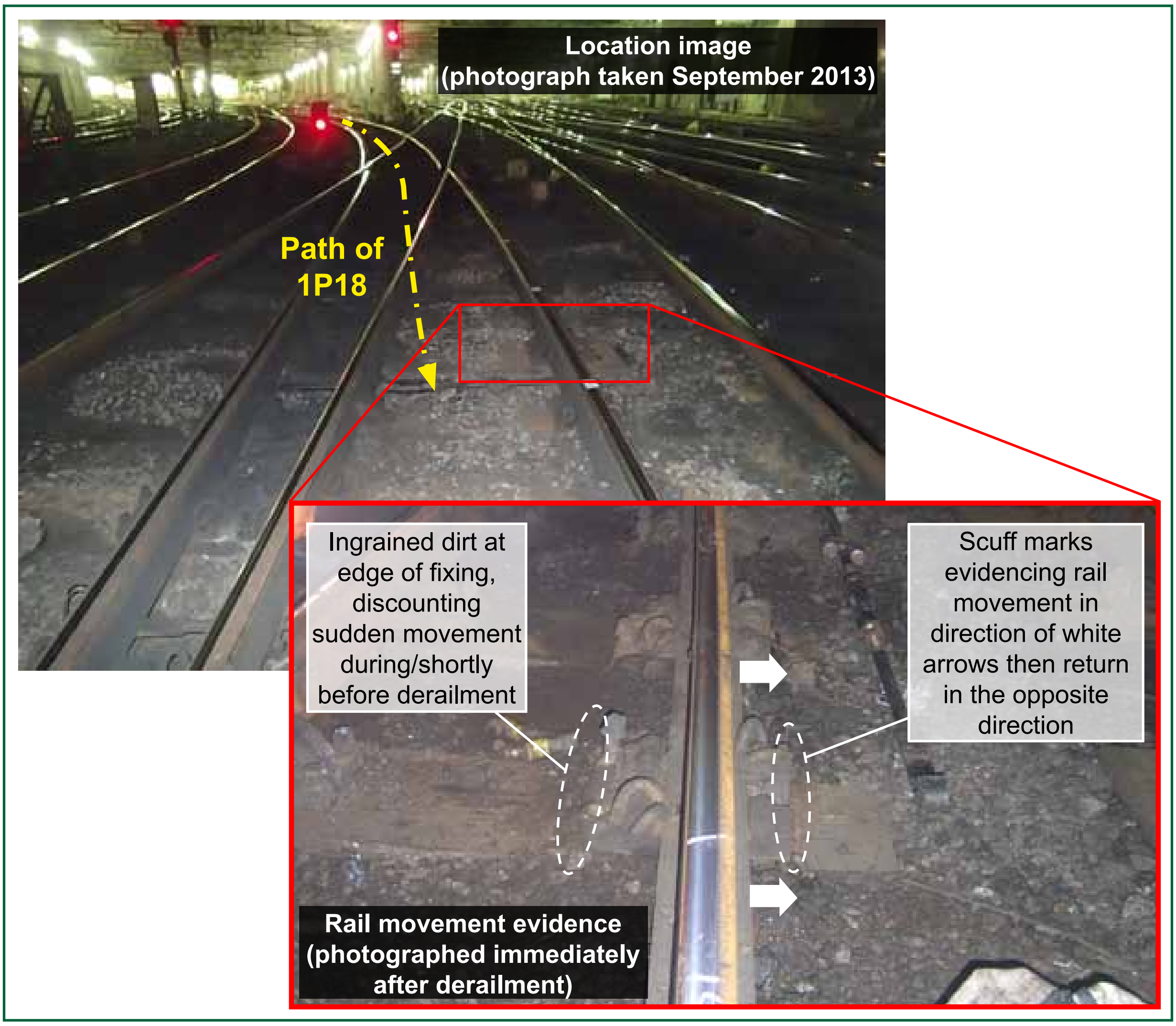

Figure 15: Wide gauge rail fixing with ingrained dirt around baseplate discounting possibility of recent movement

79 The static track gauge was measured throughout the derailment site immediately after the derailment and a value of 1474 mm was found at the drop in (derailment) marks. If found during routine inspection, Network Rail standard NR/L2/TRK/001 would require remedial action within 36 hours. Although gauge was not measured immediately before the derailment, the build up of dirt immediately behind the baseplate (figure 15) discounts the possibility that the baseplate first moved during, or shortly before the accident. Network Rail records show that the static gauge was measured on March 2012 and found to be less than 1455 mm (paragraph 122) indicating that significant deterioration had occurred over the following ten months.

80 The inspection regime intended to detect, and trigger correction of, excessively wide static gauge at Liverpool Street is described in paragraph 102.

Degraded condition of rail fixings

81 **The degraded condition of the rail fixings, on the curve between 2035B and 2035C points, made it easier for the rails to move apart when train 1P18 passed over. This was a causal factor.**

82 Forces imposed on outer rails of curves, such as the left-hand rail at the location of the derailment, can cause the rail fixings to deteriorate. The chairscrews may break, or the sleepers may deteriorate and allow the chairscrews to move. This failure allows the baseplate to move under the lateral forces imposed as wheelsets pass. The curvature of the rail will then tend to pull the baseplate back towards its correct position after wheelsets pass.

83 This repetitive movement leaves a scuff mark and/or depression on the sleeper beyond the normal position of the outer edge of the baseplate (commonly known as '*shuffle*', figure 16). This effect is well understood and normally mitigated by the regular inspection and maintenance processes required by Network Rail standard NR/L2/RK/001.

84 The scuff marks and depressions observed after the accident on the upper surface of sleepers near the point of derailment were associated with the greatest displacement of the baseplate which probably occurred during the derailment. These are likely to have obscured any scuffing and depressions associated with previous shuffle. The observed marks and depressions show that, during the derailment, the left-hand rail fixings moved laterally by up to 35 mm beyond the static gauge. The measured static gauge and shuffle marks varied at each sleeper, but when both are added together, the combined maximum measured was 1508 mm at the point of derailment. This maximum included 4 mm of wear on the left-hand rail, an amount within the limits permitted by Network Rail standards.

85 As the greatest baseplate displacement had probably occurred during the accident, it was not possible to determine the extent of any shuffle marks that may have been visible before the accident. However, evidence of pre-derailment shuffle is provided by witness marks left by sheared chairscrews found in five sleepers after the accident. These chairscrew marks were beneath the baseplate so would have not been visible before the accident.

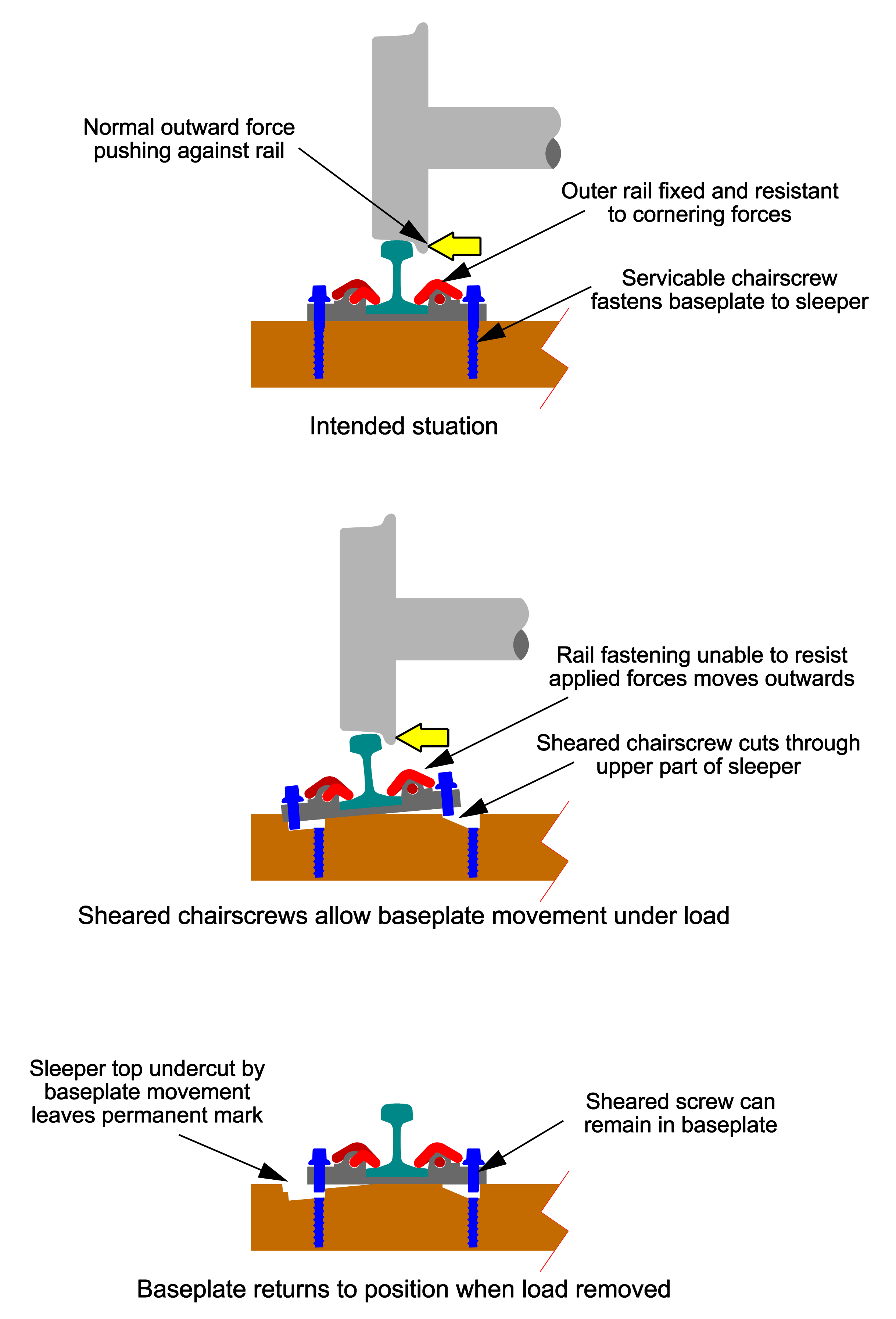

Figure 16: Baseplate shuffle and sleeper marks

86 The chairscrews had broken a short distance below the underside of the baseplate leaving a short length of chairscrew protruding downwards into the sleeper. Subsequent movement of the baseplate was evidenced by grooves cut into the upper part of the sleeper. These grooves remained after repairs were undertaken immediately following the derailment and were seen by the RAIB while permanent repairs were being undertaken in November 2013 (figure 17).

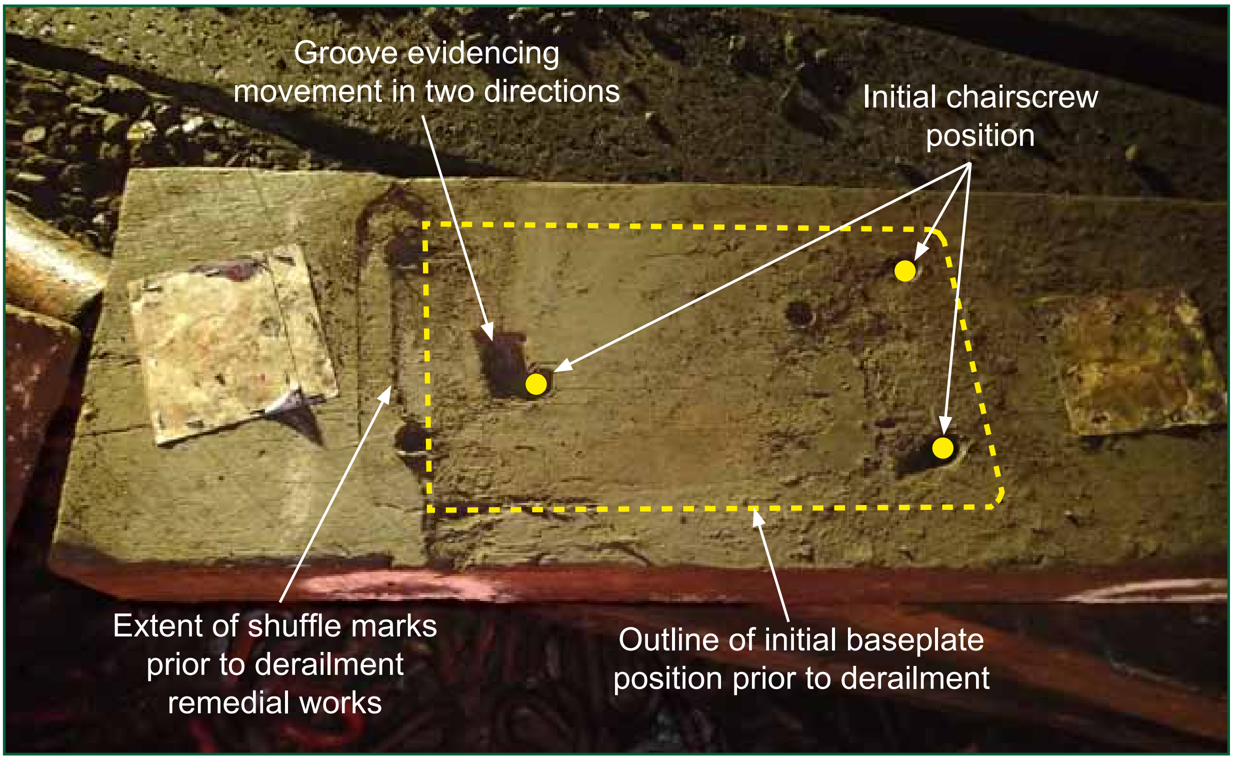

Figure 17: Marks caused by pre-derailment shuffle (post-derailment marks shown on figure 18)

87 These pre-accident grooves were much wider than the chairscrews indicating that the sides of the groove had been worn outwards by many cycles of movement. Some of the grooves had developed in more than one direction and this is inconsistent with them being caused only by movements during the derailment.

88 A sample of the sheared chairscrews were examined after the derailment and the fracture faces examined. The sample included a screw with a fully rust covered fracture surface, a screw with a clean fracture across the full width of the screw and a partially rusted screw with a remainder of the surface still shiny.

89 The fully rust covered fracture surface indicates there were screws which had fractured for some time before the derailment and remained in the baseplate as described in paragraph 87. The screws with a clean surface across the full width of the fracture face indicate the bolt had recently failed, possibly as a result of an overload as a consequence of the derailment. The part rusted fracture face indicates a crack which had formed in the screw allowing rust to penetrate, but which finally failed under load during the derailment.

90 It is possible to prevent shuffle by screwing metal blocks, known as gauge stops, into the sleeper against the outer edge of the baseplate[4]. These provide additional resistance to the outward movement of the baseplate caused by train loading. No gauge stops were found after the accident, there was no evidence of any being fitted in the past and, at the derailment location, the distance between the outer edge of the baseplate and the sleeper end was too narrow to accommodate gauge stops.

91 Where wide gauge caused by gradual deterioration is found, Network Rail standard NR/L2/TRK/001 requires the fitting of *tie bars* as a short term control measure. Tie bars clamp to the underside of both running rails and provide additional restraint to further *gauge widening* (an increase in the distance between the rails). The fitting of tie bars should be recorded and a permanent repair should be made as soon as possible, and no longer than six months from fitting. No tie bars had been provided in the vicinity of the derailment site, although they had been provided elsewhere in the Liverpool Street station area.

92 Sleepers at the derailment site did not show any evidence of poor quality or rotten wood. The condition of the sleeper wood was discounted as a factor in the derailment.

93 As part of the repairs undertaken immediately after the derailment, Network Rail turned the existing baseplates through 180 degrees and re-fixed them to the existing sleepers. The asymmetrical chairscrew hole pattern in the baseplate meant the chairscrews were then screwed into a previously unused part of the sleeper. Turning the baseplates also meant that the baseplate edges were in a slightly different position on the sleeper. It was therefore possible for the RAIB to distinguish between the effects of shuffle before and during the derailment and that which occurred later.

94 Shuffle continued to occur in the 10 months between re-fixing the baseplates immediately after the derailment and the implementation of permanent repairs in November 2013. The marks made by the lateral movement during post-accident shuffle are shown in figure 18. The post-accident shuffle was associated with sheared chairscrews which were found during the relaying works in November 2013 (figure 19).

95 The inspection regime intended to identify, and trigger correction of, shuffle is described at paragraph 102.

96 The combined distance of 1508 mm between the rails (paragraph 84) is less than the 1515 mm required for a standard wheelset to drop inside the rails. Post-accident measurement confirmed that the derailed wheelsets on vehicles 3 and 4 would all require 1515 ±1 mm to drop in between the rails, so it is necessary for the gauge to be greater than the 1508 mm described in paragraph 84. It is probable that the distance between the rails increased above 1508 mm due to rotation of the right-hand switch rail.

[4] The use of gauge stops is not referenced within the Network Rail standards. However, the RAIB is aware that gauge stops are fitted on Network Rail infrastructure. The Permanent Way Institute textbook 'British Railway Track, Volume 4, Plain Line Maintenance', 7th Edition, describes the good practice of fitting gauge stops on curves where high lateral forces are generated.

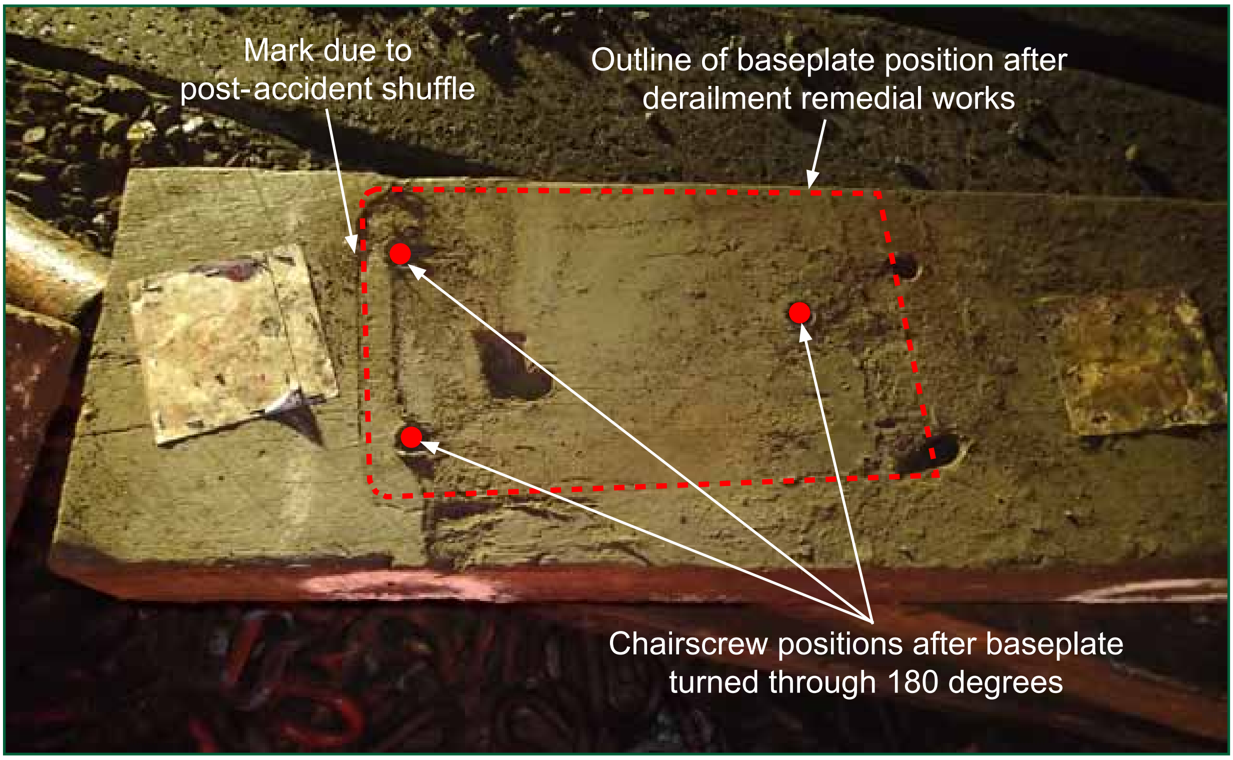

Figure 18: Marks caused by post-derailment shuffle (pre-derailment marks shown on figure 17)

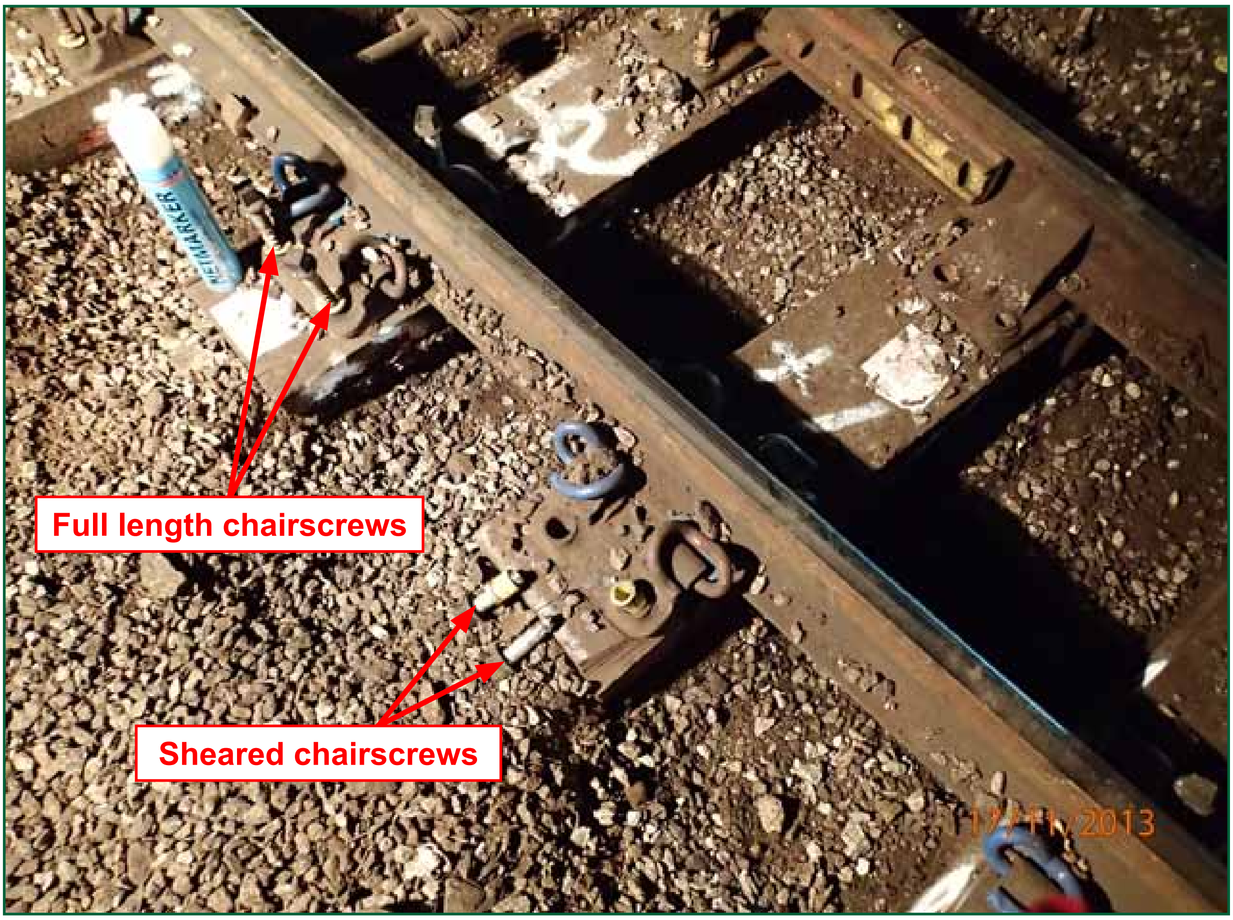

Figure 19: Sheared & intact chairscrews

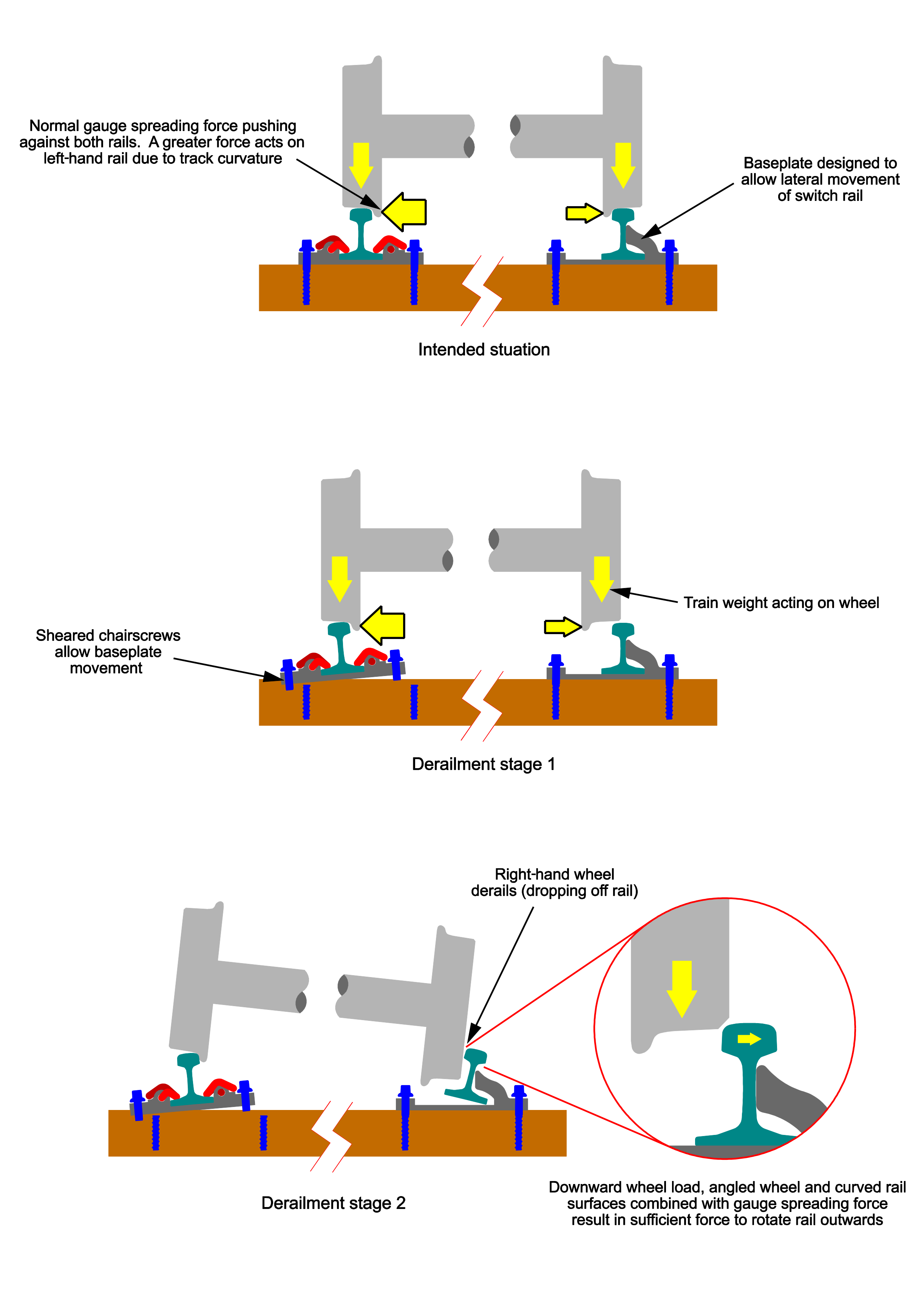

Figure 20: Derailment sequence

97 The right-hand switch rail is intended to move laterally according to the direction in which 2035B points are set (figure 7). The rail support system allowing this movement does not prevent the top of the right-hand rail moving outwards due to rotation at the foot of the rail. The right-hand rail is not normally subjected to sufficient gauge spreading force (paragraph 69) to cause movement of this type. However, in this instance, it is likely that the displaced position of the left-hand rail meant that the outer edges of the right-hand wheels were running on the inner edge of the switch rail. In this position, the downward load from the wheels, the angled shape of the wheels and the curved rail head combining with the gauge spreading force would result in the top of the switch rail being pushed outwards (figure 20, inset).

Increased gauge spreading force

98 **The increase in the gauge spreading force, arising from the static wide gauge and rail deflection due to the reduced strength in the rail fixing, resulted in additional deflection of the rails when train 1P18 passed over. This was a causal factor.**

99 The vehicle dynamics study commissioned by the RAIB following the Liverpool Central and Ordsall Lane Junction derailments identified that widened track gauge (paragraph 79) generates a greater gauge spreading force on the rails than track of standard gauge. This tendency for widening gauge to cause higher gauge spreading forces meant that loads on the track fixings at Liverpool Street were increased due to the wide static gauge (paragraph 75). They then further increased as movement of the outer rail due to fixing deterioration (paragraph 81) led to a further gauge increase. There was also a tendency for gauge spread forces to increase under successive wheelsets of a train. This was because each wheelset was encountering track which had been subject to the gauge widening effects of previous wheelsets.

100 Although gauge spread was occurring at the derailment site, outside this immediate area the outer rail remained secured to its fixings so the rail sprang back towards its original position after the wheelsets passed. This could occur both between successive wheelsets of the same train and between successive trains. However, the cumulative effect of successive movements led to increasing fixing deterioration, and thus both permanent deformation (the wide static gauge) and an increasing maximum deflection under load. These effects increased until the deflection under load was sufficient to cause the derailment.

101 The on train data recorder shows that there was an application of power from the locomotive at the time that vehicle 3 passed through the derailment site (a normal occurrence). This application of power from the locomotive at the rear would have changed the distribution of forces along the train and at the wheel/rail interface and is a possible reason why this was the first vehicle to derail.

Inspection regime

102 The inspection regime was not sufficient to detect track fixing deterioration; this was because:

- manual inspections did not report, and possibly did not identify, wider than normal static track gauge or indications of a loss of strength in the fixing between the rail and sleepers (paragraph 103);
- automated track monitoring and associated data analysis did not identify the combined effect of widened static track gauge and loss of strength in the fixing between the rail and sleepers (paragraph 115); and
- no consideration had been given to providing an enhanced inspection regime for the non-standard track layout, and consequently no special mitigation measures had been implemented, (paragraph 128).

These are now considered in turn:

Manual inspections

103 **Manual inspections did not report, and possibly did not identify, wider than normal static track gauge or indications of a loss of strength in the fixing between the rail and sleepers (paragraphs 75 and 81). This was a causal factor.**

104 For *standard track* (ie track not requiring a special inspection regime due to an enhanced derailment risk), Network Rail standard NR/L2/TRK/001 requires inspections to be carried out at regular intervals determined by the weight, frequency and maximum permitted speed of trains using the track. The requirements give a hierarchy of inspections which vary in interval and content, each carried out by different grades of track maintenance staff.

105 The inspection requirements for standard track were being applied at the incident site before the derailment and meant that a *basic visual inspection* was undertaken at weekly intervals by a *patroller.* This inspection was intended to identify and report defects which could affect the safety of trains in the following four weeks. The basic visual inspection does not require measurement of static gauge. A visual inspection would not have the accuracy needed to detect the changes of static gauge (up to 20 mm, paragraph 122) which had been occurring over a ten month period at the accident site.

106 Network Rail standard NR/L2/TRK/001 required patrollers to report shuffle if the extent of marks had ‘visibly increased’. However, they were not required to record the amount of shuffle so this requirement relied on patrollers remembering the amount of shuffle visible during their previous inspection.

107 It is certain that shuffle was occurring before the derailment (paragraphs 85 and 87) and that shuffle marks were visible before the derailment. The rate at which shuffle developed before the accident cannot be established so there is no way of knowing whether it ever increased at a rate sufficient to cause the ‘visibly increased’ shuffle which patrollers are expected to report (paragraph 105). If this did occur, it is not possible to determine when it occurred. There is no mention of shuffle on available inspection records for the 10 weeks before the accident (Network Rail was unable to provide complete records for this period).

108 Network Rail standard NR/L2/TRK/001 also requires that static gauge should be measured at sample locations during quarterly supervisors inspections by the section manager [track] (SM[T]). The standard requires the SM[T] to select the location of their sample check based on local knowledge of the track conditions. The SM[T] stated that he would normally measure gauge every quarter mile (approximately 400 metres), at either side of points or anywhere he considered there to be a problem. The record of the most recent inspection before the derailment, undertaken in November 2012, contains no record of excessive static gauge at the derailment site. As standard NR/L2/TRK/001 does not require the location of acceptable gauge measurement to be recorded, it is uncertain whether a measurement was taken at the derailment site.

109 The standard also requires that both shuffle and shearing of chairscrews should be recorded during the quarterly supervisor's inspections. Both had been noted in other inspections undertaken by the SM[T] in other areas near Liverpool Street station, but none were reported at the derailment site on the November 2012 inspection, the last undertaken before the derailment. The extent of shuffle, if any, present in November 2012 cannot be established due to uncertainties described in paragraph 107.

110 A detailed inspection of the points, including assessing track gauge, should have been undertaken by the SM[T] every 52 weeks in accordance with standard NR/L2/TRK/001. This standard included a specific requirement to inspect for shuffle and indications of gauge widening.

111 Network Rail uses *Ellipse* software to manage track inspection and maintenance tasks. This software records required tasks, produces task lists and records when the tasks have been completed.

112 A Network Rail audit dated November 2012 found no records of detailed inspections for 2035A, 2035B or 2035C points in the 52 weeks prior to the audit. The audit also noted that a clerical error meant that inspections of these points were not included in Ellipse and so had not been included in the task lists supplied to the SM[T]. There is no evidence of these inspections having been undertaken in the period between the audit and the derailment. Network Rail was unable to identify an assurance process (other than sample based audits such as that carried out in November 2012) which checks that Ellipse contains the correct inspection and maintenance tasks for all assets intended to be included within the database.

113 Standard NR/L2/TRK/001 required the track maintenance engineer (TME) to carry out a visual inspection of all track, on foot, every two years. It also required the TME to undertake an annual cab ride over all passenger lines although this was not required to include all routes through junctions, all loops or all platforms. The last TME inspection which included the derailment site took place on foot in May 2012.

114 Network Rail standards did not give a precise specification for the activities to be undertaken by the TME during his visual inspections. In May 2012, three night shifts were allocated for the TME to inspect the line from Liverpool Street to Bethnal Green, a distance of about 1.1 miles (1.8 km) and including all the tracks shown on figure 2. This was not intended to allow the TME to undertake a detailed inspection of all track in this area, but to allow sample checking and examination of areas of specific concern. The TME had not identified any issues at the site of the derailment before the accident.

Assessment of dynamic gauge widening

115 **Automated track monitoring and associated data analysis did not identify the combined effect of widened static track gauge and loss of strength in the fixing between the rail and sleepers (paragraphs 75 and 81). This was a casual factor.**

116 Network Rail standard NR/L2/TRK/001 requires that the track inspection process includes an assessment of *dynamic gauge*, the distance between the rails when carrying train loads. The *intervention limit* for triggering maintenance activities given in this standard relates to dynamic (not static) gauge. At the incident site, the standard required track geometry, which includes measurement of dynamic gauge, to be assessed at a ‘nominal planning interval’ of 24 weeks and a maximum interval of 52 weeks.

117 In most locations, *track recording trains* measure dynamic gauge directly and thus record the combined effect of wide static gauge and any rail movement under train loads due to a loss of strength in the fixings. Wide static gauge and dynamic movement were present at the derailment site (paragraph 75 and 81), but they could not be measured by a track recording train because the train does not record results when travelling at or below the maximum permitted speed of 15 mph (24 km/h) at Liverpool Street. Network Rail’s response to a previous recommendation which relates to the assessment of track that cannot be measured by the track recording train is given at paragraph 164.

118 Where dynamic gauge cannot be measured using the track recording train, standard NR/L2/TRK/001 requires manual measurements to be undertaken. Although this is not fully detailed in the standard, this requires measurement of the static gauge and an assessment of the rail movement under traffic. These measurements are then combined to give the dynamic gauge necessary for the comparison to the maintenance intervention limit (paragraph 116). Post-accident assessment by the RAIB showed that these limits had been exceeded before the accident, but it has not been possible to determine when this condition had been reached (paragraph 107).

119 At Liverpool Street the static gauge was recorded using a manual recording device known as an Amber trolley (figure 21). The trolley is lightweight to allow handling by a single person and only applies a small load to the rails. This load is not sufficient to replicate the dynamic movement caused by train loads and so the trolley cannot be used alone to measure dynamic gauge.

120 The trolley measures and records track gauge, and other track geometry characteristics, while it is pushed along the track. It alerts the operator when pre-set track geometry intervention limits, including those for dynamic gauge, have been exceeded. Although the intervention limit relates to dynamic gauge, the trolley is only measuring static gauge.

Figure 21: Amber trolley in use (not at accident site)

121 The use of the Amber trolley at Liverpool Street was first implemented in 2008 by the previous assistant track maintenance engineer, he supervised the members of the TME's technical team undertaking the task. The lengths of track to be measured in each shift were provided on task lists generated by Ellipse (paragraph 111). These lists omitted some areas of track at Liverpool Street, but did include the derailment site. The last Amber trolley measurements at the derailment site were made in March 2012, about ten months before the derailment. This was within the 52 weeks maximum interval required by Network Rail standards (paragraph 116).

122 Staff used the measurement alerts given by the Amber trolley to identify areas of track where measurements indicated a need for action according to the intervention criteria given in standard NR/L2/TRK/001. They recorded areas requiring action on paper forms. The derailment site is not included on these records, suggesting that, when measured in March 2012, the static gauge was less than the 1455 mm at which standard NR/L2/TRK/001 required remedial work to be planned[5].

123 Although the Amber trolley records both gauge and the distance travelled as it is pushed along the track, it was not possible to determine the actual gauge measured at the incident site in March 2012. This is because the operators at Liverpool Street did not always record the start position and/or pass continuously from start to finish over each section of track to be assessed. Without an accurate start point and distance travelled record, it is not possible to determine the measured gauge at a particular location.

[5] The planning of any work at this location should have taken account of the increased gauge (1441 mm compared to the standard value of 1435 mm) intended by the track designer to assist train cornering on the tight curve.

124 The last Amber trolley runs undertaken at the derailment site before the incident occurred prior to the appointment of the current ATME. The current ATME had not appreciated the lack of reliable information about the location of gauge measurements recorded electronically by the Amber trolley until they were highlighted during the Network Rail investigation into the derailment.

125 The RAIB did not find any evidence that dynamic movements under train loading were being measured (or estimated) and added to the Liverpool Street Amber trolley static gauge data to give dynamic gauge.

126 Although the use of the Amber trolley was introduced after the current TME had been appointed, the TME was also not familiar with the limitations of the data it produced. The TME did not review the process implemented by the previous ATME and incorrectly believed it to be a complete alternative to the track recording train. During the course of the investigation, the RAIB identified another TME, at a different location, who had also not appreciated the limitations of only using the Amber trolley data to assess dynamic track gauge.

127 The SM[T] understood the need for dynamic measurement of the track, but wrongly believed that the complex layout and restrictive access arrangements prevented any method of dynamic assessment. Safe access to the accident location was restricted by the intensive train service. However, it is possible to estimate dynamic movement, without the need to watch the passage of a train, by measuring the shuffle marks present on the sleepers (paragraph 83, figures 18 and 19) during routine or enhanced inspections. The RAIB found no evidence that the practicalities of obtaining improved access arrangements, or applying alternative solutions for assessing dynamic gauge, had been considered at Liverpool Street.

The need for an enhanced inspection regime

128 **No consideration had been given to providing an enhanced inspection regime for the non-standard track layout, and consequently no special mitigation measures had been implemented. This is considered to be a causal factor.**

129 The track layout at Liverpool Street was designed and installed in the late 1980s. It featured some very tight curves and a high proportion of non-standard points to fit the layout within a tight railway corridor. Current Railway Group standard GC/RT5021, 'Track system requirements', generally requires a minimum design radius of 200 metres for track used by passenger trains. However, it permits a 150 metres radius in exceptional circumstances when a larger radius cannot be provided. If a track radius of less than 200 metres is required, a check rail should be provided where practicable to reduce the lateral forces applied to the outer rail.

130 The derailment occurred within the movable area of non-standard points which incorporated a 125 metre right-hand radius curve and was not provided with a check rail. This tight curve without a check rail exposed the track to increased lateral forces which accelerated the normal rate of wear to the left-hand rail and associated track fixings.

131 Irregularities and very small cracks in the surface of the rail head, known as *head checking,* were found during an examination by the RAIB in September 2013 (figure 22). Head checking was not seen immediately after the accident, but the surface had been smoothed by recent *rail head grinding*, a process intended to grind off the metal containing small cracks before these grow large enough to cause a broken rail.

132 Head checking is caused by the transfer of forces along the track at the wheel/rail interface and is commonly found in terminal stations as a result of traction and braking forces acting longitudinally along the rail. Head checking can also occur on the rail head of tight radius curves at other locations, due to wheels slipping on the rail head. This slipping happens because wheels on the inner and outer rails rotate together, but the distance travelled along the inner rail is less than that along the outer rail. The RAIB made enquiries with other Network Rail engineers who stated that they would not enhance the inspection regime due to head checking alone, but would consider doing so if there were also other indicators of high lateral forces such as shuffle or broken fastenings.

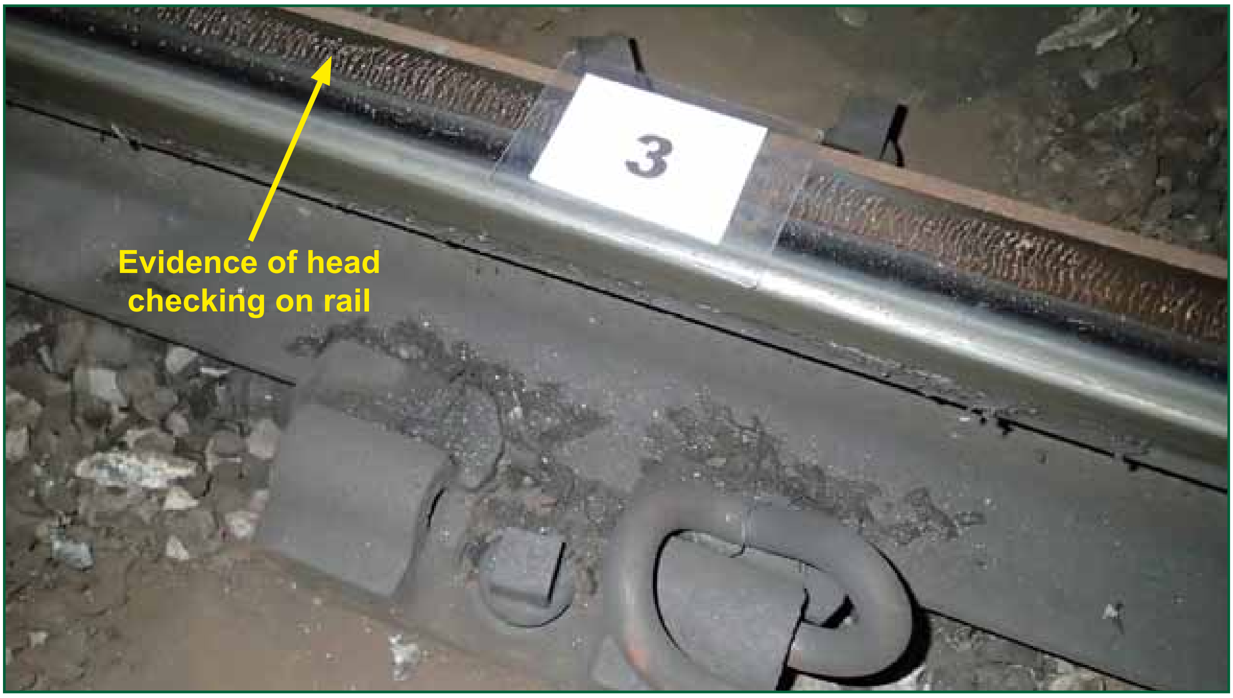

Figure 22: Head checking found on the running rail ten months after the derailment

133 Although Network Rail mandates the interval, type and content of track based inspections for standard track found on the mainline network, it does not provide explicit instructions for non-standard track such as the complex junction at Liverpool Street station. However, standard NR/L2/TRK/001 does require the TME, assisted by the SM[T], to identify safety risks arising from non-standard track assets and to apply appropriate mitigation measures where higher risk is anticipated[6]. Mitigation can include changes to the frequencies and/or content of the inspection and/or maintenance regimes.

[6] This is a summary of detailed requirements given in sections 4, 4.1, 6.1 and 6.3 of the introductory text to standard NR/L2/TRK/001 issue 5.

134 At the time of the derailment, no additional risk from the track layout at Liverpool Street had been identified and therefore no special risk mitigation measures had been implemented. The absence of any special mitigation measures to address the additional risk factors at this location is considered to be a causal factor.

135 Network Rail has not identified any process which would require such an evaluation, and any associated mitigation identified as necessary, to be documented. Such a process would enable the review and independent checking of the assessment.

Identification of underlying factors[7]

Failure to ensure asset risk management

136 **Neither the TME, nor the SM[T] had identified the need for a non-standard inspection and maintenance regime at Liverpool Street.**

137 Network Rail's standards require that a track inspection and maintenance regime should be implemented that will ensure the operational safety of the line. Issue 3 of NR/L2/TRK/001 (dated 26 August 2008) stated:

> *'The track inspection regime is based on risk, both safety and commercial, deterioration rates, anticipated failure modes and the identification of work needed so that it may be carried out in a planned way'.*

138 Issue 4 of NR/L2/TRK/001 (dated 05 December 2009) expanded on this requirement stating:

> *'It is important that the most appropriate frequency and methods of inspection are used that will provide the SM[T] and TME with the assurance that the infrastructure remains fit to use at its designed line speed and collect information that will monitor condition and drive timely maintenance'.*

139 The need to assess derailment risk arising from the track asset was implicit in the need to develop an inspection regime which was based on safety risk. However this was made an explicit requirement for the SM[T] and the TME to identify and manage risk arising from track assets in NR/L2/TRK/001 issue 5 (dated 02 June 2012). This stated:

> *'The TME and SM[T] must be able to identify risk from the track assets, assess those risks and take action to control them. These are continuous processes that TME and SM[T]s must follow, using results of inspections and the full range of track asset information that is available to them'.*

140 The track layout at Liverpool Street utilises many non-standard design features that were necessary to allow the track to fit within the tight railway corridor. These include tight radius curves and intended gauge variations, sometimes close to or exceeding those permitted by current design standards. Some of these features, such as the small radius curve at the derailment site, were likely to cause an increased risk of derailment. At the time of the accident no special inspection or maintenance plan had been implemented to control the increased derailment risk.

[7] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

141 The SM[T] and TME both believed that there were no unusual derailment risks associated with the track at Liverpool Street. The TME was also not aware that the track design at the derailment site included features likely to cause an increased risk of derailment. They therefore implemented the inspection regime given in standard NR/L2/TRK/001 for track without such features.

142 The SM[T] and TME each had nearly 30 years track maintenance experience, but had not received formal training in identifying unusual track layouts likely to import an increased risk of derailment. Such training would highlight the circumstances where track geometry, non-standard track design or the local operating conditions might lead to an increased derailment risk.

143 Without the ability to determine risk, the SM[T] and TME were reliant on the transfer of knowledge, or intervention by others. The TME stated that there was no overlap with, or handover from, the previous TME. During the course of the investigation, the RAIB has noted that the extent of handover arrangements for TMEs at other locations has varied and does not always include direct communication between the previous and new postholders. Network Rail standard NR/L2/TRK/001 issue 5 requires the IME to ensure this handover occurs, but this was issued after the appointment of the current TME.

Failure to manage technical knowledge shortcomings

144 **The IME did not appreciate, and so did not manage, shortcomings in the technical knowledge of the TME and his team.**

145 Issue 5 of Network Rail standard NR/L2/TRK/001 became effective on 01 September 2012 and introduced two explicit IME responsibilities which, if effectively implemented, would have led to the recognition, and correction, of shortcomings in the dynamic gauge assessment and track risk identification processes. The standard stated that IMEs must:

> *'confirm that SM[T] and TME can demonstrate knowledge and understanding of identifying risk to the track assets, risk assessment and taking action to control risk'*

> *'arrange training and coaching for SM[T]s and TMEs and address shortfalls in knowledge and understanding of risk, applying controls where necessary to mitigate shortfalls'*

146 Neither the SM[T] nor the TME had the knowledge or training to enable them to identify potential derailment risks arising from the track asset as required by the Network Rail standard (paragraphs 140 to 142). The TME did not appreciate that dynamic gauge was not being assessed (paragraph 126) as required for all track by Network Rail standard NR/L2/TRK/001.

147 Formal Network Rail competence assessments stop at the track supervisor level, the grade below SM[T]. SM[T]s are assessed against the track supervisor requirements, but with no additional assessment to cover their more senior responsibilities. Consequently there was no comprehensive formal competence assessment or management system in place for SM[T] or TME grades, so it was necessary for the IME to assess competence using his own knowledge or arrange an assessment by others.

148 The IME came from an electrical engineering background and had limited experience of track design and maintenance. However, IMEs are not required to have comprehensive knowledge of the technical disciplines represented by all the maintenance engineers reporting to them. They can draw on the experience of other staff to provide such knowledge when necessary.

149 The TME was in post when the IME was appointed and the IME understood that he was an experienced and competent member of the track maintenance staff. This opinion was shared by many others within the MDU who had worked with the TME for many years.

150 Network Rail standard NR/L2/TRK/001 issue 5 became effective after the IME was appointed and gave no explicit instructions about how it should be applied to existing post holders. Neither did the standard give examples of how the TME's knowledge of risk related to track assets (eg derailment risk) could be assessed if the IME does not have personal experience in track maintenance.

151 The IME could not provide examples of checks that he had carried out, or others had carried out on his behalf, which would provide confirmation that the SM[T] and TME could identify derailment risk. The IME believed he could request the RAM[T] to assess the TME for competence in identifying derailment risk, but the RAM[T] was not asked to do so.

152 The TME, IME and RAM[T] all acknowledged that the RAM[T] role includes the mentoring of TMEs. However, without a specific request from the IME this arrangement would have relied on the TME asking for assistance. At Liverpool Street there was a good working relationship between the TME and the RAM[T]. However, the TME did not believe there was a need to seek additional assistance and did not do so.

153 In summary, the RAIB has concluded that the absence of a process to ensure the competence of the SM[T] and the TME to identify locations with high derailment risk, and the lack of an assurance process to validate their assessment of this risk, led to the adoption of an inappropriate inspection regime at Liverpool Street. As a result the inspection regime that was implemented was not sufficient to detect deterioration of the track fixings at the derailment site before the track failed. This absence of a competence assurance process for the track maintenance discipline is addressed in Recommendation 2. It is possible that a comparable competence assurance process is also required for maintenance staff with responsibilities similar to SM[T]s and TMEs but in other disciplines. This is particularly relevant because an IME is unlikely to have comprehensive knowledge about all the disciplines reporting to them,. This issue is addressed in Recommendation 3.

Observations[8]

Inspection records

154 During the course of the RAIB investigation, Network Rail was unable to provide records of some maintenance inspections. In particular, the RAIB found evidence of work being carried out in response to findings from inspections for which the corresponding paper records were not available. Witness evidence states that the filing system for paper records was disorganised.

155 Network Rail standard NR/L2/TRK/001 requires maintenance reports and records to be kept for a minimum of three years. These records not only confirm the completeness of inspections and provide evidence for competency assessment, they also provide historical asset data.

156 Historical asset data can be used as the input to trend analysis which, over time, can provide information about the potential failure modes and condition of the fixed infrastructure. In areas of non-standard infrastructure, such as the track at Liverpool Street, trend data can be used as part of a control measure to ensure the adequacy of the asset maintenance strategy.

Communication during the incident

157 It is possible that better communications between the service manager and incident controller, both located at the AICC, could have led to an earlier recognition that a derailment might have occurred, and thus earlier recognition that the train needed a rigorous technical inspection before being allowed to remain in service (paragraphs 29 to 39). Although these communication shortcomings did not affect the consequences of the Liverpool Street derailment, the consequences could have been serious in other circumstances.

[8] An element discovered as part of the investigation that did not have a direct or indirect effect on the outcome of the accident but does deserve scrutiny.

Summary of conclusions

Immediate cause

158 The derailment occurred as train 1P18 negotiated the small radius curve at 2035B points because the outer rail fixings of the left-hand rail on the curve were unable to resist the lateral forces acting at the wheel/rail interface. The forces were sufficient to widen the track gauge such that the right-hand wheels on the trailing bogie of the third vehicle dropped between the rails (**paragraph 59**).

Causal factors

159 The causal factors were:

a. the wide static track gauge, which had developed on the curve between 2035B and 2035C points, reduced the margin that was available for the rails to safely deflect when train 1P18 passed over (**paragraph 75**);

b. the degraded condition of the rail fixings, on the curve between 2035B and 2035C points, made it easier for the rails to move apart when train 1P18 passed over (**paragraph 81**);

c. the increase in the gauge spreading force, arising from the static wide gauge and rail deflection due to the reduced rail fixing strength, resulted in additional deflection of the rails when train 1P18 passed over (**paragraph 98**);

d. manual inspections did not report, and possibly did not identify, wider than normal static track gauge or indications of a loss of strength in the fixing between the rail and sleepers (**paragraph 103, Learning points 2 and 3, Recommendation 1**);

e. automated track monitoring and associated data analysis did not identify the combined effect of widened static track gauge and loss of strength in the fixing between the rail and sleepers (**paragraph 115, Learning points 3 and 4, Recommendation 1**); and

f. no consideration had been given to providing an enhanced inspection regime for the non-standard track layout, and consequently, special mitigation measures had not been implemented (**paragraph 128, Recommendation 1**).

Underlying factors

160 The RAIB has identified two underlying factors which led to this situation. These are:

- Neither the TME, nor the SM[T], had identified the need for a non-standard inspection and maintenance regime at Liverpool Street (**paragraph 136, Recommendation 2**).
- The IME did not appreciate, and so did not manage, shortcomings in the technical knowledge of the TME and the SM[T] **(paragraphs 144 and 153, Learning point 5 and Recommendations 2 and 3**).

Additional observations

161 The RAIB found that records of maintenance inspections were not available due to shortcomings in the filing system. The Network Rail standards required records to be kept for a minimum of three years. These records confirm completeness of inspections, assist competency assessment and can assist development of maintenance strategies (**paragraphs 154 to 156, Learning point 6**).

162 Shortcomings in communications between staff in the AICC could have had serious consequences in other circumstances (**paragraph 157, Learning point 1**).

Previous RAIB recommendation relevant to this investigation

163 The RAIB considers that earlier completion of the following recommendation could have prevented this accident by identifying the wide static gauge and loss of strength in the track fixing.

Derailment at Windsor and Eton Riverside, 11 October 2009

164 The RAIB investigation into a passenger train derailment at Windsor and Eton Riverside station (RAIB report 11/2010, published on 05 August 2010) found that dynamic track faults had not been identified by the track recording train or by an alternative manual method. The derailment occurred at a location which was not assessed by a track recording train because of the low speed.

165 Following this derailment, the RAIB made this recommendation:

Recommendation 2

Network Rail should develop a proposal for the periodic measurement of dynamic gauge at potentially vulnerable locations not covered by a track recording vehicle, and implement the identified measures, as appropriate.

166 The Office of Rail Regulation reported to the RAIB in October 2013 that this recommendation had been 'implemented by alternative means' and provided the following supporting information:

Network Rail has considered how potentially vulnerable parts of the network that are not covered by Track Recording Vehicles (TRV) can be subject to dynamic gauge measurement. Network Rail has delivered additional training to track maintenance engineers and is evaluating the feasibility of direct measurement of dynamic gauge at slower speed at potentially vulnerable locations not covered by a track recording vehicle.

167 This investigation demonstrates that the interim solution was not effective at Liverpool Street. Therefore, the RAIB is concerned that Network Rail had still to develop an effective solution more than three years after the recommendation was published (this concern was recorded in the RAIB 2013 annual report). Network Rail has stated that a track recording vehicle capable of operating at slow speeds was introduced on an experimental basis in 2014 and is programmed for use in 2015.

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

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

168 Network Rail undertook emergency repairs to the track in the immediate vicinity of the track failure following the derailment. Since then, the sleepers and fixings in the derailment area have been replaced.

169 Network Rail has reported that dynamic track gauge is now being recorded throughout the Liverpool Street area and that an experienced track engineer is assessing track condition, and making recommendations for enhancements to the inspection and maintenance regime, at Liverpool Street.

170 Network Rail and Greater Anglia have stated that AICC staff have been briefed on the need for effective liaison when dealing with events which may involve both trains and track. Network Rail has nominated a route control manager to monitor the quality of safety-critical communications within the AICC.

Learning points

171 The RAIB has identified the following key learning points[9]:

1 The importance of prompt and effective communication between train and track controllers when dealing with events which could be associated with urgent safety issues (paragraph 162).

2 The need to check that Ellipse contains the correct inspection and maintenance tasks for all assets intended to be included within the database (paragraph 159d).

3 The need for effective management of track gauge, including in areas of intensive train services, where this is not monitored by track recording trains (paragraph 159d and 159e). Available techniques include:

- looking for visual indicators, (eg shuffle marks, *running band* position[10] and head checking) which show that rails could be moving under trains;
- identification of broken or loose fixings (ie those which allow rails to move when subject to train loads) by simple manual testing;
- observing rail behaviour while trains are passing;
- combining static gauge measurements with dynamic rail movements assessed from visual indicators (possibly implemented only if visual indicators suggest a problem);
- direct measurement of rail movement including the consideration of technical solutions such as dynamic track gauges and electronic monitoring where personnel access is limited (possibly implemented only if visual indicators suggest a problem); and
- identification of repeat defects indicative of track being inadequate for the loads being imposed on it.

4 Staff using Amber trolley data should be aware that, although pre-programmed to generate alerts related to dynamic gauge intervention limits, the trolley is only recording static gauge and so could mislead the operator. Users must assess dynamic movement by alternative means and take this into account when assessing whether maintenance intervention is necessary (paragraph 159d and 159e).

[9] '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.

[10] The strip of polished metal on the rail head indicating the path followed by train wheels. If displaced from the usual position, the rail is not correctly aligned with the wheels, possibly because it is moving beneath trains.

5 The importance of IMEs managing the competence of SM[T]s and TMEs in accordance with the requirements given in NR/L2/TRK/001 (paragraph 160). This states that IMEs must:

- confirm that SM[T]s and TMEs can demonstrate knowledge and understanding of identifying risk to the track assets, risk assessment and taking action to control risk;
- arrange training and coaching for SM[T]s and TMEs to address any shortfalls in their knowledge and understanding of risk;
- applying controls to mitigate risk where this is needed until any shortfalls in SM[T]s and TMEs knowledge and understanding of risk have been addressed; and
- arrange transfer of knowledge of high risk locations from previous postholders to SM[T]s and TMEs when they take responsibility for a new area or route.

6 The need to archive inspection and maintenance records as a minimum in accordance with NR/L2/TRK/001, or as required to meet the needs of the inspection and maintenance regime implemented by the maintenance management team (paragraph 161).

Recommendations

172 The following recommendations are made[11]:

1 *This recommendation is intended to reduce the risk of derailment arising from the performance of non-standard track assets by establishing an appropriate and independently checked inspection regime.*

Network Rail should improve its management systems so that both the identification of all non-standard track assets, and the associated inspection regimes intended to manage any enhanced risk of derailment, are recorded and independently checked. The scope of these inspection regimes should include mechanisms for identifying indications of possible gauge widening and, where necessary, assessing dynamic track gauge (paragraphs 159d to 159f).

2 *This recommendation is intended to introduce an assessment of staff in track related safety critical roles where the role is reliant on judgements made by that member of staff, to ensure they have the necessary experience and knowledge to perform that role.*

Network Rail should introduce a timebound programme for assessing (and reassessing at intervals) the competence of its managers with safety critical roles linked to track maintenance (eg section managers [track] and track maintenance engineers), and addressing any shortfalls arising (paragraph 160).

3 *This recommendation is intended to establish whether it is appropriate to extend the aims of recommendation 2 beyond the track discipline.*

Network Rail should introduce a timebound programme for the review of the processes used for assessing (and reassessing at intervals) the competence of managers with safety critical roles linked to the maintenance of assets other than track, and addressing any shortfalls arising (paragraph 160).

[11] 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 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 the 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 the RAIB's website www.raib.gov.uk.

Appendices

Appendix A - Glossary of abbreviations and acronyms

AICC	Anglia Integrated Control Centre
ATME	Assistant track maintenance engineer
DRAM	Director of route asset management
IECC	Integrated Electronic Control Centre
IMDM	Infrastructure maintenance delivery manager
IME	Infrastructure maintenance engineer
MDU	Maintenance Delivery Unit
RAIB	Rail Accident Investigation Branch
RAM[T]	Route asset manager [track]
RMD	Route managing director
SM[T]	Section manager [track]
TME	Track maintenance engineer

Appendix B - Glossary of terms

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

Anglia Route	A sub division of the Network Rail infrastructure and the associated resources for operation and maintenance. The geographical area includes London to Shoeburyness, Southend, Norwich, Cambridge, King's Lynn and Great Yarmouth.
Back (of a wheel)	The reverse face of a rail wheel not normally visible from the side of the train and not in contact with the running rail.
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.
Baseplate	A metal plate which supports the rail on the sleeper.
Bogie (on incident vehicles)	An assembly of two wheelsets in a frame which is pivoted at the end of a long vehicle to enable the vehicle to go round curves.
Chairscrew	A steel screw which attaches the baseplate to the wooden sleeper.
Check rail	A rail or other special section provided alongside a running rail to give guidance to flanged wheels by restricting lateral movement of the wheels.*
Colour light signal	A railway signal which uses coloured lights to indicate whether the driver has to stop, needs to be prepared to stop or can proceed without restriction. The lights may show: ● Green - proceed, the next signal may be displaying green or yellow; ● Yellow - caution, be prepared to stop at the next signal as it may be displaying a stop signal when you reach it; and ● Red – stop.
Control centre of the future (CCF)	A system used by control centre staff and others which provides a visual schematic display of train position, both real-time and historic, and presents information on train running.
Detection	A failsafe arrangement that proves that a set of points are correctly set in position. Correct detection must be obtained before trains can pass over the points.
Driving van trailer	An un-powered rail vehicle with a driving cab at one end which, when attached at the opposite end of a train to the locomotive, allows a single locomotive to haul the train in both directions.
Dynamic gauge	The distance measured between the running rails while the track is under load from a train. (See also static gauge.)

Electric multiple unit	An electric train consisting of one or more coaches, including at least one powered vehicle, with driving cabs at each end, which can be coupled to other units and operated as a single train.
Ellipse	A computer based asset management system used by Network Rail to record and prioritise what maintenance is work required to be done and when it needs to be done by.
Fishplate	Specially cast or forged steel plates used in pairs to join two rails at a 'fishplated' rail joint.*
Foot (of rail)	The lower part of a rail section.*
Gauge (of track)	The distance measured between the inside faces of the running rails.
Gauge widening (of track)	An increase in track gauge as a result of intended design or unintended rail movement.
Head checking	A more general term for a rolling contact fatigue (RCF) defect found in the running band of the rail head.*
Incident controller	A Network Rail employee who manages Network Rail's response to incidents, liaising with railway industry and other parties as appropriate.
Integrated Control Centre	The co-location of Network Rail and train operating control centres.
Integrated Electronic Control Centre (IECC)	A type of signal control system that controls the points and signals for a whole route or a large geographical area by electronic means. The signallers' interface is normally a monitor, keyboard and pointing device.
Intervention limit	The threshold value of a defect at which remedial action is required.
Joint (rail)	A mechanical joint between two rails held in line and supported by the fixing of two plates either side of the adjoining rail ends.
Leading bogie (or wheel)	The bogie (or wheel) at the front of the vehicle (or bogie) in the direction of travel. (See also trailing bogie (or wheel).)
Loss of detection	Relating to points, the situation that exists when points are not proved to be in the position commanded by the signalling system.
On Train Data Recorder (OTDR)	A data recorder fitted to a train that records information on the status of train equipment, including speed and brake applications.
Patroller	A competent person whose duties are to carry out a basic visual track inspection and minor maintenance.
Plain track	A section of railway track which does not include any points.

Points	A pair of moveable switches that direct trains between two tracks; two pairs of points are required to form a switch diamond (figure 7).
Rail (head) grinding	The use of manual tools or a specialist train to grind the rail head to remove surface imperfections and reshape the rail to its required profile.
Running band	That part of the running rail upon which the majority of vehicle wheels make contact. It appears as a shiny strip on the rail head. The location and consistency of location of this strip can tell an observer much about track geometry and track gauge.*
Running rail	A rail that supports and guides the flanged steel rail wheels of a rail vehicle.*
Run through (points)	To force a train wheel through the converging rails at a set of points when the points are not set for a movement from that direction.
Shearing (shear failure)	Deformation (or fracture) in which parallel planes in a body remain parallel.
Shuffle (baseplate)	The tendency of inadequately maintained baseplates on wood sleepers to move laterally under traffic, so wearing the wood away from under them.*
Signaller's display	The visual interface between the signaller and the signalling system depicting a schematic railway layout, train positions and status of the signalling in real time.
Signalling shift manager	The senior post in the signalling centre operations room responsible for managing the operation of the signalling centre staff for that working shift.
Sleeper	A beam made of wood, 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 gauge is maintained between the rails.*
Spring clips	The collective term for any rail fastening system that relies on the spring action to perform its function.*
Standard track (as used in this report)	Track not requiring a special inspection regime due to an enhanced derailment risk.
Static gauge	The distance measured between the running rails while the track is not loaded by the presence of a train. (See also dynamic gauge).
Switch (rail)	The movable rail which forms part of a set of points.
Switch diamond crossing	Two tracks crossing at such an acute angle or curvature that moving rails are required to maintain clearance for the rail wheel flange (appendix D).

Technical riding inspector	A member of the train operator's maintenance staff that usually travels on board train services in order to provide a quick response to minor train maintenance requirements.
Tie bar	Adjustable metal bar temporarily fixed between running rails and used to maintain gauge.
Tip (of a switch rail)	The top corner at the moving end of a switch rail that is reached first by a train travelling over the points in a diverging direction.
Track circuit block	A signalling system which operates by automatically detecting the absence of a train by electrical circuits through the track.
Track fastening	A sub-component of the track fixing system used to secure baseplates to sleepers or rails to baseplates.
Track fixings	The mechanical system of components which position and secure a rail to the sleeper.
Track recording train	A specially equipped train that automatically measures and stores track geometry information for the lines that it runs over.
Trailing bogie (or wheel)	The bogie (or wheel) at the rear of the vehicle (or bogie) in the direction of travel. (See also leading bogie (or wheel).)
Train services manager	A member of the control centre staff employed by the train operator to monitor train services and respond to incidents relating to train services.
Wheelset	Two rail wheels mounted on their joining axle.

Appendix C - Key standards current at the time

Railway Group standard GC/RT5021	Track system requirements
Network Rail standard NR/L2/TRK/001 version 5	Inspection and maintenance of permanent way
Network Rail standard NR/L3/TRK/002 version 7	Track Maintenance Handbook
Network Rail specification NR/SP/CTM/011 version 1	Competence and Training in Track Engineering

Appendix D - Switched diamond crossings

D1 Diamond crossings are provided where one railway track must cross another at the same level allowing trains to cross the opposing line, but not connect to it. The angle between the railway tracks creates a diamond shape in the centre. These diamond crossings are usually combined with points to form part of a more complex junction arrangement as found on the approach to London Liverpool Street (figures D1 and D2).

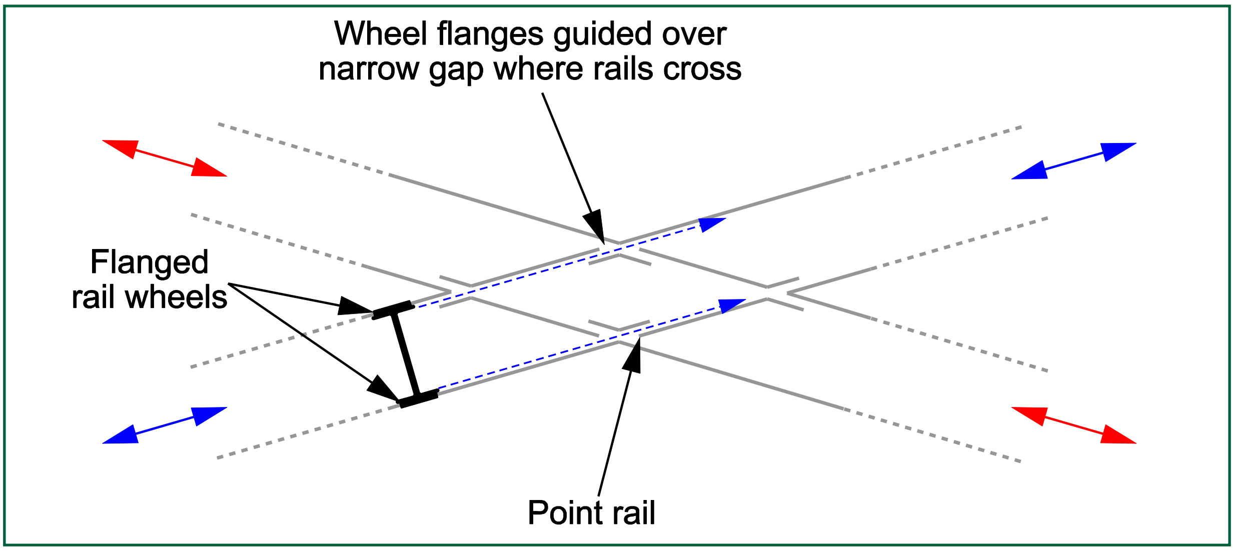

Figure D1

Figure D2

D2 To allow the rail wheel flanges to cross the opposing track, the rails are bent to create flangeway gaps. Where the angle between the tracks is quite large the flangeway gap is short enough between the point rails to provide continuous guidance to the passing wheel. This design of diamond crossing, known as a fixed diamond, does not require any moving parts.

D3 At certain locations where the running rails must cross each other at a much smaller angle, or if one or both tracks are curved, the distance between the point rails becomes much longer. If the gap becomes too long there is a risk of the wheel flange striking, or passing the wrong side of, the point rail (figure D3).

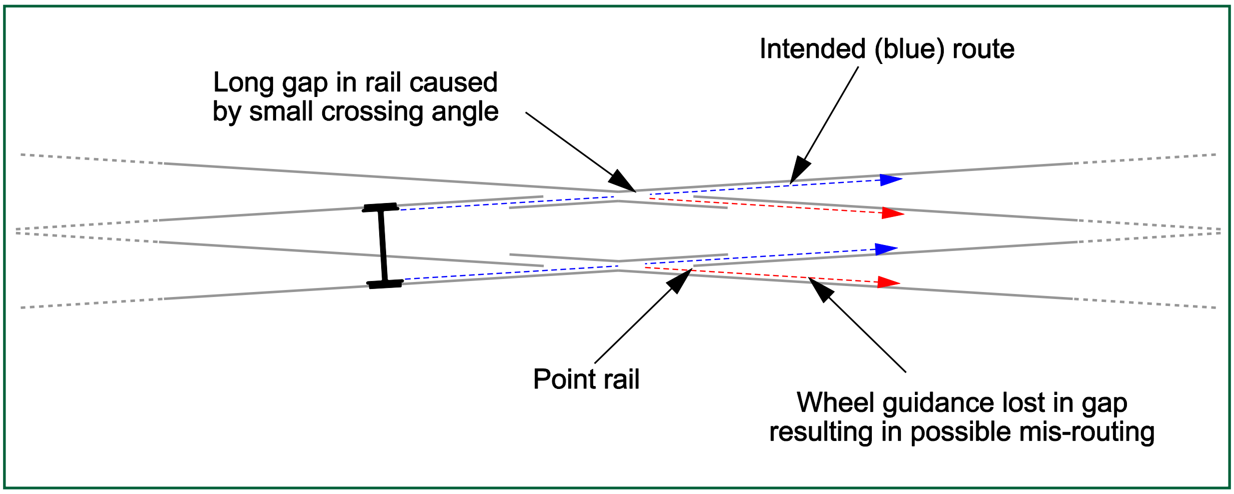

Figure D3

D4 At these locations switch diamonds are provided to avoid the need for gaps between the rails. This type of crossing features two pairs of moveable rails to provide a continuous path for train wheels as they cross between running rails, thereby removing the need for the wheels to negotiate a gap (figure D4).

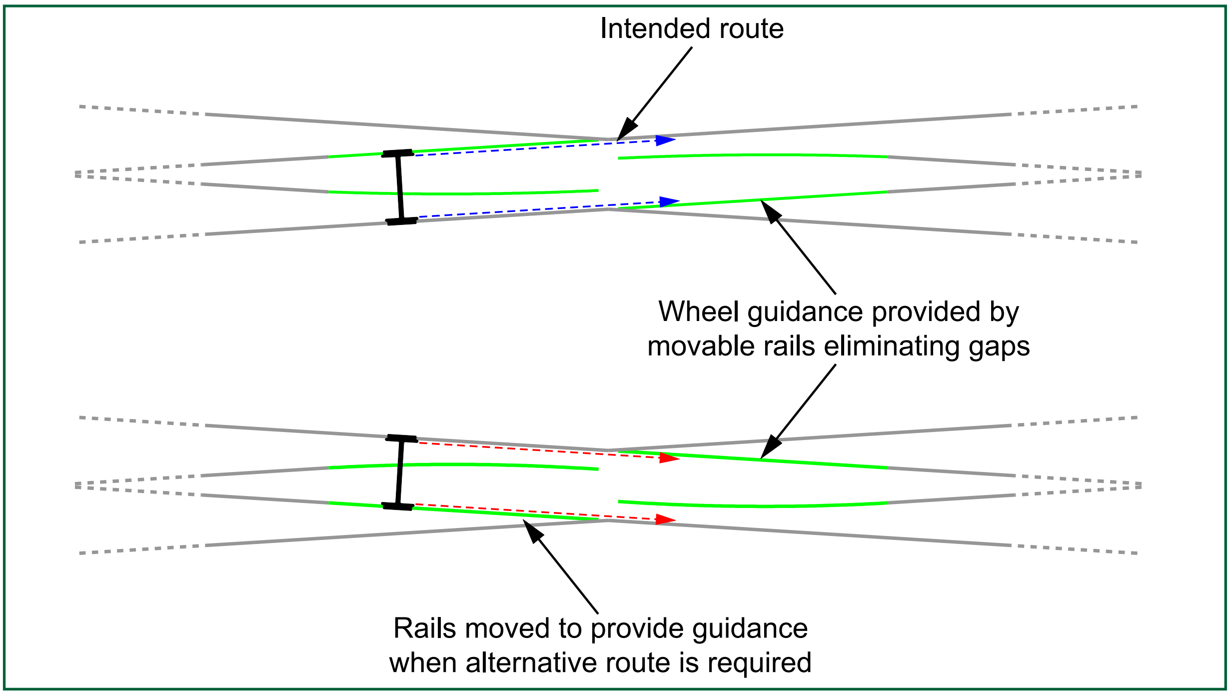

Figure D4

D5 These moveable rails can then by moved aside to allow the free passage of the wheel flanges on a train crossing on the other track. The position of each pair of moveable rails is therefore dependent on which of the two tracks is to be used by a train and is set by the signaller. The correct positioning, locking and detection of the moveable rails is ensured by the railway's signalling system.

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