RAIB

Rail Accident Investigation Branch

Rail Accident Report

Collision between passenger trains at Salisbury Tunnel Junction, Wiltshire
31 October 2021

Report 12/2023
October 2023

This investigation was carried out in accordance with:

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

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Preface

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

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

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

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

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

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

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

Any information about casualties is based on figures provided to RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. RAIB recognises that sudden unexpected events can have both short- and long-term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

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

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Collision between passenger trains at Salisbury Tunnel Junction, Wiltshire, 31 October 2021

Contents

Summary

At around 18:43 hrs on 31 October 2021, train reporting number 1L53, the 17:20 hrs South Western Railway passenger service from London Waterloo to Honiton, passed a red signal and collided with the side of train 1F30, the 17:08 hrs Great Western Railway passenger service from Portsmouth Harbour to Bristol Temple Meads. At the point of collision, train 1L53 was travelling at approximately 52 mph (84 km/h) and train 1F30 at 20 mph (32 km/h). The collision took place at Salisbury Tunnel Junction, which is on the immediate approach to Fisherton Tunnel, near Salisbury in Wiltshire.

The impact of the collision caused the front two carriages of train 1L53 and the rear two carriages of train 1F30 to derail. Both trains continued some distance into Fisherton Tunnel before they came to a stop. Thirteen passengers and one member of railway staff required treatment in hospital as a result of the accident, which also caused significant damage to the trains and railway infrastructure involved. A potentially far more serious collision between train 1L53 and an earlier train travelling in the opposite direction was avoided by less than a minute.

The causes of the accident were that wheel/rail adhesion was very low in the area where the driver of train 1L53 applied the train's brakes, that the driver did not apply the train's brakes sufficiently early on approach to the signal protecting the junction to avoid running on to it, given the prevailing low level of adhesion, and that the braking systems of train 1L53 were unable to mitigate this very low adhesion.

The level of wheel/rail adhesion was very low due to leaf contamination on the railhead, and had been made worse by a band of drizzle that occurred immediately before the passage of train 1L53. This leaf contamination resulted from the weather conditions on the day of the accident, coupled with an increased density of vegetation in the area which had not been effectively managed by Network Rail's Wessex route. Network Rail's Wessex route had also not effectively managed the contamination on the railhead with either proactive or reactive measures.

RAIB's investigation found that a probable underlying factor was that Network Rail's Wessex route did not effectively manage the risks of low adhesion associated with the leaf fall season. RAIB also found that South Western Railway not effectively preparing its drivers for assessing and reporting low adhesion conditions was a possible underlying factor.

RAIB has also made two safety observations. These relate to the application of revised design criteria for the Train Protection and Warning System and the assessment of signal overrun risk and how this accounts for high risk of low adhesion sites. Two issues were found relating to the severity of the consequences. These were a loss of survival space in the driver's cab of train 1L53, and the jamming of internal sliding doors, which obstructed passenger evacuation routes.

Since the accident, Network Rail has reviewed its training and competence framework for off track staff at network level, and is also reviewing its adhesion management standards. Network Rail's Wessex route is reviewing its arrangements for proactively responding to reports of low adhesion, including how it undertakes railhead treatment.

South Western Railway has made changes relating to training and briefing of its drivers to ensure information on autumn arrangements has been effectively briefed and understood.

Network Rail and South Western Railway have also jointly updated their annual autumn leaf fall working arrangements to ensure that sites at high risk of low adhesion are identified, reassessed, managed and monitored.

The Rail Safety and Standards Board has revised the rail industry standard that provides guidance for the rail industry regarding the management of low adhesion. Cross-industry working groups have also issued revised guidance regarding low adhesion.

In December 2021, the safety authority for the mainline railway in Great Britain, the Office of Rail and Road, issued an improvement notice to Network Rail's Wessex route requiring it to improve its vegetation management and its assessment and control of low adhesion risks.

As a result of the investigation, and accounting for the work done by the industry since the accident, RAIB has made ten recommendations. Seven of these recommendations are made to Network Rail. These relate to: a review of the processes, standards and guidance documents relating to the management of leaf fall low adhesion risk; the training and competence of staff dealing with vegetation management and seasonal delivery; responses to emerging and potential railhead low adhesion conditions; management of railhead treatment regimes; assessment of the risk of overrun at signals which have a site at high risk of low adhesion on their approach; and a review of the retrospective application of design criteria for the Train Protection and Warning System.

One recommendation is made to South Western Railway to review and improve its arrangements for training and briefing drivers to ensure that they are able to effectively identify areas of low adhesion and report them as appropriate.

One recommendation is made to the Rail Delivery Group in consultation with train operators and the Rail Safety and Standards Board regarding the review of technologies other than sanding systems and wheel slide protection to improve braking in low adhesion conditions.

One recommendation is made to Porterbrook, Eversholt and Angel Trains regarding the design of the internal sliding doors on class 158 and 159 carriages.

Introduction

Definitions

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

2 The terms 'up' and 'down' refer to the lines heading towards and away from London Waterloo station, respectively. For ease of reference, some distances in this report are also measured from the accident site. Mileages given in the report are measured from a datum at London Waterloo.

3 The report contains abbreviations. These are explained in appendix A. Sources of evidence used in the investigation are listed in appendix B.

The accident

Summary of the accident

4 At around 18:43 hrs[1] on Sunday 31 October 2021, train reporting number 1L53, the 17:20 hrs South Western Railway passenger service from London Waterloo to Honiton, collided with the side of train 1F30, the 17:08 hrs Great Western Railway passenger service from Portsmouth Harbour to Bristol Temple Meads. Train 1L53 was travelling at approximately 52 mph (84 km/h)[2] and train 1F30 at 20 mph (32 km/h). The collision occurred at Salisbury Tunnel Junction, which is on the approach to Fisherton Tunnel, near Salisbury in Wiltshire (figures 1 and 2).

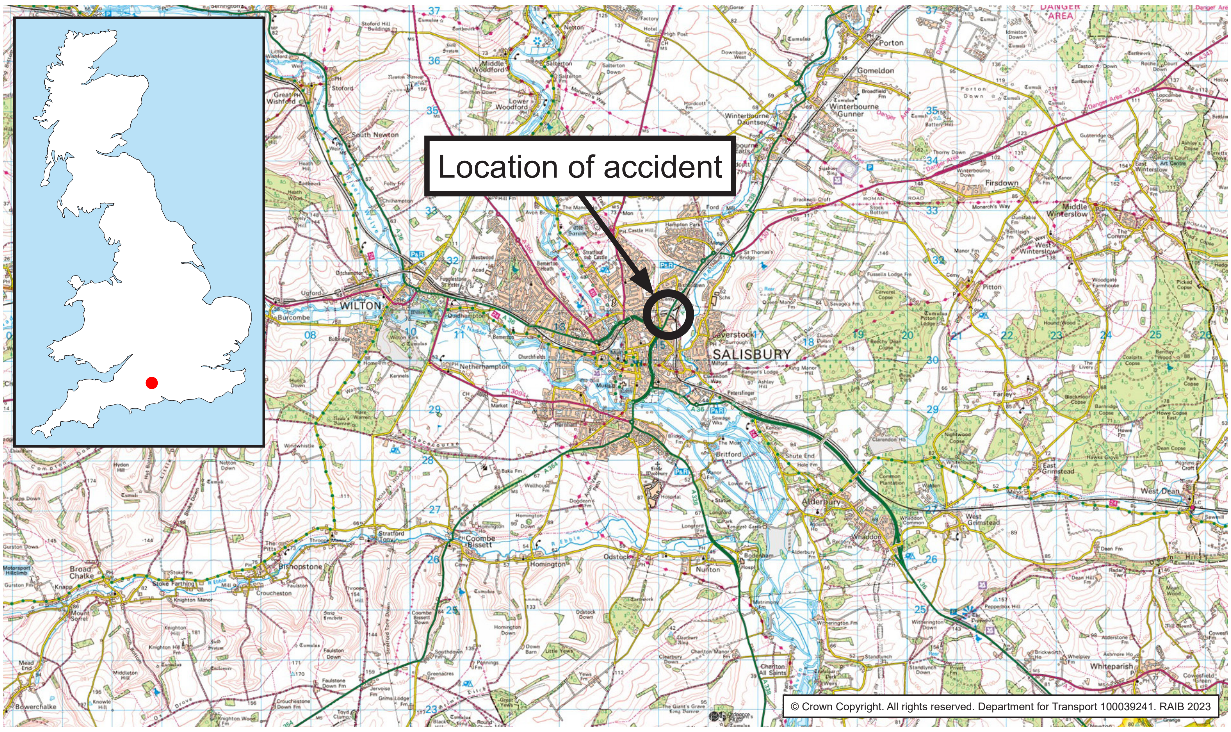


Figure 1: Extract from Ordnance Survey map showing the location of the accident at Salisbury Tunnel Junction.

5 The movement of train 1F30 across the junction was being protected from trains approaching on the Down Main line by signal SY31, which was displaying a red (danger) aspect. The signal had previously been protecting another train, train 1F27, which passed over the junction in the opposite direction less than a minute before the accident. Train 1L53 passed this signal by around 200 metres before colliding with train 1F30 (figures 3 and 4).

6 The impact of the collision caused the front two carriages of train 1L53 and the rear two carriages of train 1F30 to derail. Both trains continued some distance into Fisherton Tunnel following the collision before they came to a stop.

[1] The times shown in the report have been adjusted to synchronise with the signalling system time.

[2] On a class 159, the speed signal recorded by the on-train data recorder (OTDR) is derived from the rotational speed of the second wheelset. When this wheelset slides, the recorded speed will be less than the actual speed of the carriage. Therefore, it is possible that at times, train1L53 was travelling at a higher speed than that recorded by the OTDR during the accident.

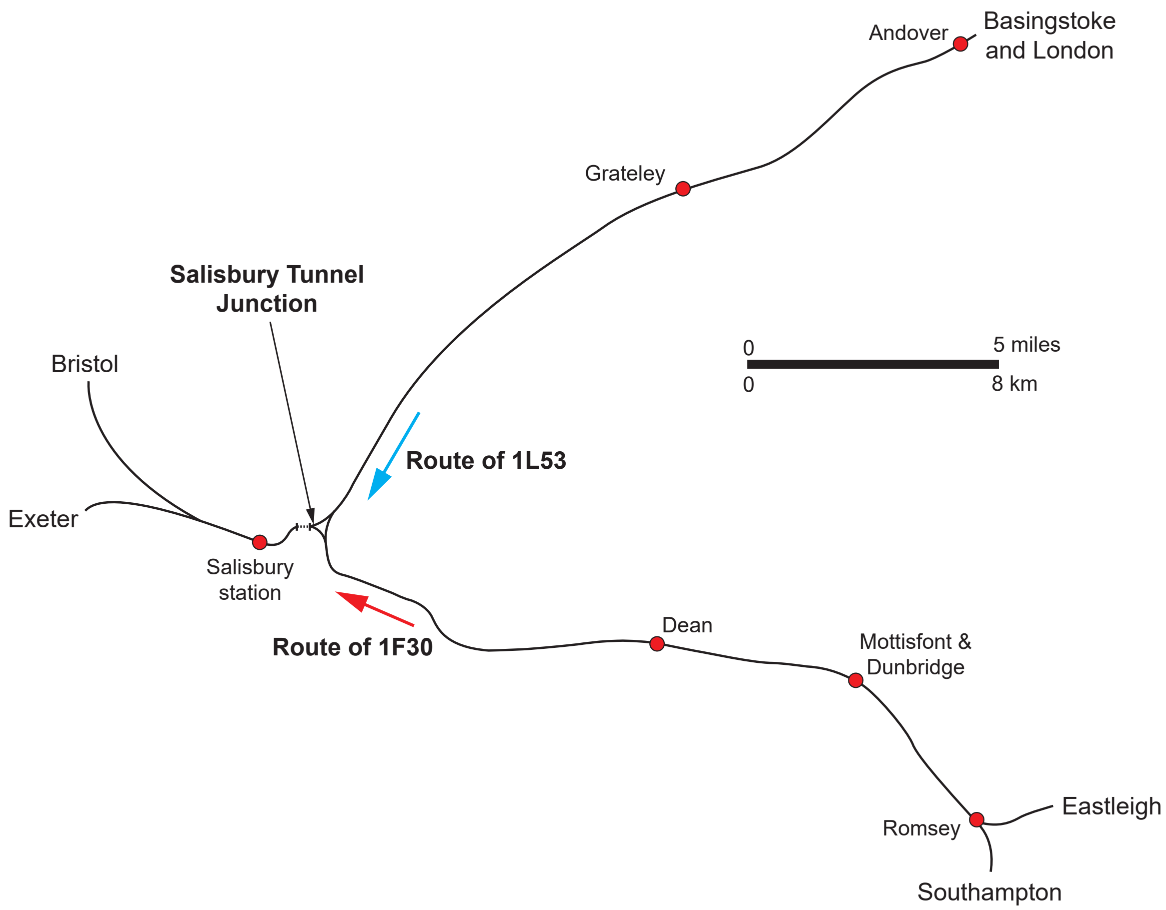


Figure 2: Overview of the location of the accident and geographical relationship of the main features.

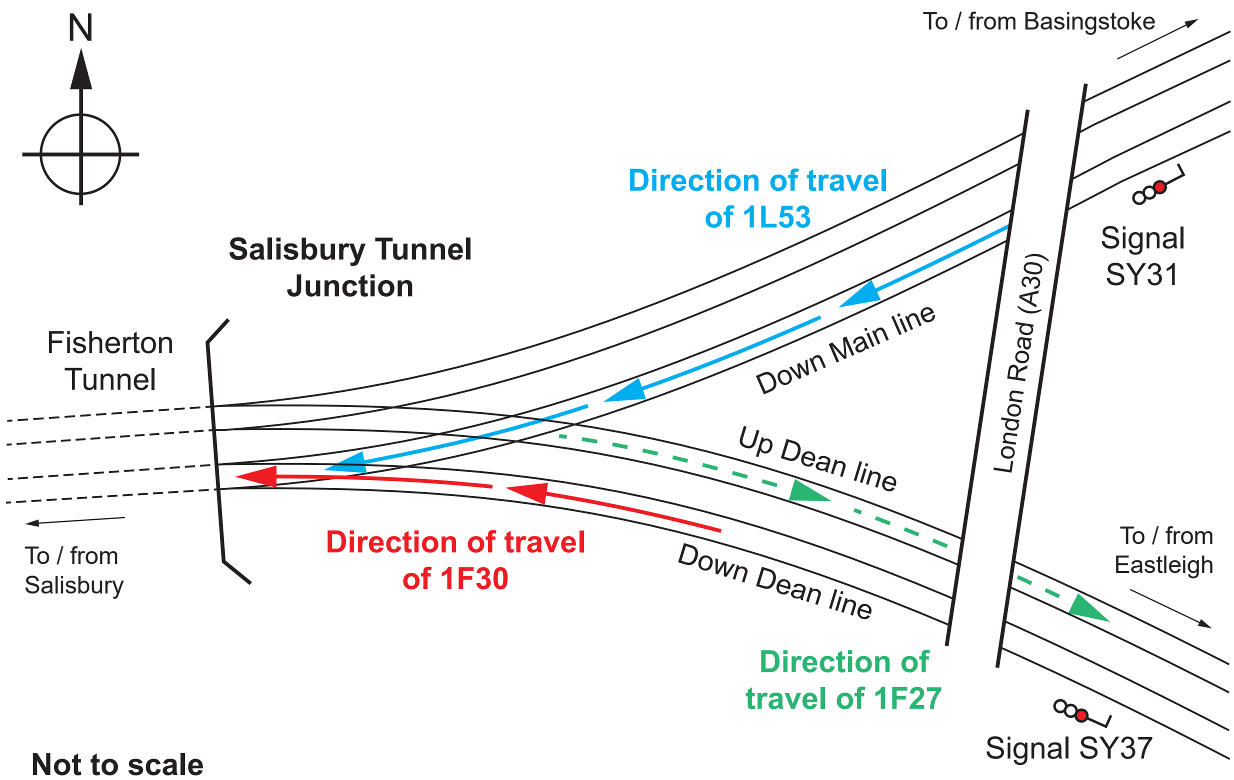


Figure 3: Diagram of the location showing the direction of train 1F27 that had just passed over Salisbury Tunnel Junction and the approach of trains 1L53 and 1F30 to Fisherton Tunnel.

Figure 4: The aftermath of the accident.

7 The accident caused substantial damage to the track, the tunnel and the surrounding railway infrastructure. The leading carriage of train 1L53 and the rear two carriages of train 1F30 were damaged beyond economic repair. The rear two carriages of train 1L53 were less seriously damaged and the leading two carriages of train 1F30 were undamaged.

8 The driver of train 1L53 was seriously injured in the accident and spent three weeks in hospital. Thirteen passengers were also taken to hospital, with one suffering serious injuries. A further ten passengers were treated at the scene for cuts and bruises.

9 In total, there were 197 passengers and five members of staff on the two trains. Each train had a driver and a guard on board. There was also an on-duty driver travelling as a passenger on train 1F30 when the accident occurred.

Context

Location

10 At Salisbury Tunnel Junction, the Up and Down Main lines, which run to and from London Waterloo via Basingstoke, meet the Up and Down Dean lines, which run to and from Southampton via Romsey. Beyond the junction is the 405 metres (443 yards) long Fisherton Tunnel and, just over 1 mile (1.6 km) further west, Salisbury station. The collision occurred around 200 metres after train 1L53 had passed signal SY31, at 82 miles 35 chains from London Waterloo.

11 The maximum permitted speed for trains approaching the junction on the Down Main line is 90 mph (145 km/h), reducing to 50 mph (80 km/h) approximately 700 metres before the junction. Drivers are informed of the 50 mph (80 km/h) speed restriction by a warning board about 1,400 metres on approach to its start, and the start of the speed restriction itself is indicated by a commencement board.

12 Due to a sharp curve, the maximum permitted speed on the Down Dean line approaching the junction is 20 mph (32 km/h).

Organisations involved

13 The railway infrastructure at Salisbury is owned, operated and maintained by Network Rail. Salisbury Tunnel Junction forms part of Network Rail's Wessex route which, along with the Kent and Sussex routes, forms part of the Southern region. Each Network Rail region acts as a devolved management organisation within the company.

14 Due to the size of the Wessex route, maintenance and inspection of the infrastructure is split between outer and inner maintenance delivery units (MDUs). The Salisbury line falls under the responsibility of the Wessex outer MDU.

15 Network Rail employs the signallers at Salisbury signal box, autumn control room staff at the Wessex integrated control centre (WICC) in Basingstoke, the seasons delivery specialist (SDS) and the lineside and drainage senior asset engineer (SAE). It also employs the MDU engineering and inspection off track staff, who manage the control and inspection of vegetation.

16 Network Rail Supply Chain Operations, part of Network Rail Route Services, organises the contractual arrangements and route schedules for the Wessex route railhead treatment multi-purpose vehicle (MPV) fleet. Although Network Rail's Wessex route is the fleet's owner and entity in charge of maintenance, operation of the MPV fleet and the actual undertaking of the maintenance is contracted out.

17 Train 1L53 was operated by First MTR South Western Trains Ltd, trading as South Western Railway (SWR). SWR employed the train driver and the guard of this train.

18 Train 1F30 was operated by First Greater Western Ltd, trading as Great Western Railway (GWR). GWR employed the train driver and guard of this train.

19 Porterbrook Leasing owned the carriages which formed trains 1L53 and 1F30 and leased them to the train operators concerned.

20 Network Rail and SWR together undertook an internal railway industry investigation into the accident ('the joint industry investigation', see paragraph 334).

21 All parties freely co-operated with RAIB's investigation.

Staff involved

22 The driver of train 1L53 started his railway career in 1962 with British Railways, working as a fireman on steam locomotives and later as a train driver's assistant. He started driving trains for British Rail in 1982 and, following privatisation of the industry, was employed by South West Trains and latterly SWR as a driver and driver instructor. The driver had been based at Salisbury depot for his entire career and had moved to a part-time contract in 2019.

23 The driver had been deemed competent to drive trains by SWR and all his competence assessments were in date in accordance with the company's train driver competency management process. These assessments included defensive driving techniques relating to low adhesion, against which the driver demonstrated his competence between August 2018 and July 2021, as part of a three-year competence assessment cycle, and was due to be reassessed in 2024.

24 At the time of the accident, the driver was working two days a week, driving class 158 and 159 trains between London Waterloo and Exeter, Southampton and Basingstoke, as well as on the Salisbury to Bristol route. For the week starting 25 October 2021, the driver worked on Tuesday 26 and Saturday 30 October. He was then scheduled to work nine-hour shifts on Sunday 31 October, the evening of the accident, and Monday 1 November 2021.

25 The SDS joined Network Rail in late 2019 on the graduate entry scheme. They were initially seconded as an assistant supporting the then incumbent Wessex route SDS, during which time they also gained experience as a track patrol assistant. They later transferred to London Waterloo, returning to their SDS support role in early 2020. After the incumbent SDS was transferred to another role, they took up the position of Wessex Route SDS on a permanent basis.

Railway systems and infrastructure involved

26 Signalling in the area is controlled from a signal box at Salisbury station. On the Down Main line, Salisbury Tunnel Junction is protected by signal SY31, a three-aspect colour light signal. Signal SY31 is located at 82 miles 25 chains, around 200 metres from the point where the collision occurred. Although signal SY31 had been passed at danger twice before, in May 2001 and May 2006, neither of the signals passed at danger (SPADs) were documented as being caused by low adhesion.

27 Before reaching signal SY31, trains approaching the junction on the Down Main line will first pass signal SY29R (80 miles 30 chains) and then signal SY29 (81 miles 66 chains), as shown in figure 5 and further discussed in paragraph 186. These are approximately 3,320 metres and 980 metres from the point of collision, respectively. If signal SY31 is displaying a red aspect, signal SY29R will display a double yellow (preliminary caution) aspect and signal SY29 will display a single yellow (caution) aspect.

28 The gradient beyond signal SY29R is 1 in 169 descending, before it levels out again on approach to signal SY29. Beyond signal SY29 the gradient is 1 in 733 descending (from 81 miles 67 chains), increasing to 1 in 610 descending (from 82 miles 6 chains). This latter gradient encompasses the line on approach to and beyond signal SY31 and towards the point of the collision and Fisherton Tunnel (82 miles 37 chains).

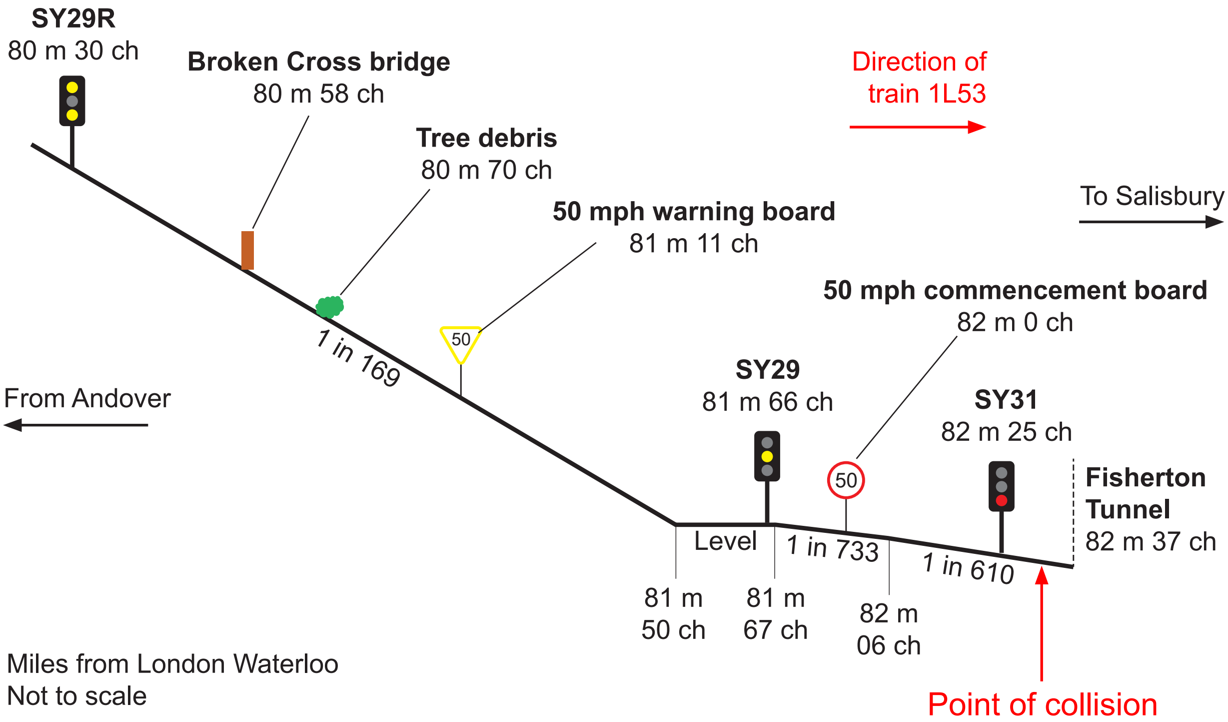


Figure 5: Signalling layout, gradient profiles and distances on approach to the point of collision.

29 For trains approaching on the Down Dean line, the protecting signal for the junction is signal SY37, located 120 metres from the point of the collision.

30 To reduce the risk from signals being passed at danger, Automatic Warning System (AWS) and Train Protection and Warning System (TPWS) equipment is provided in the area controlled by Salisbury signal box.

31 AWS provides an audible and visual warning to a driver on the approach to signals as well as some other infrastructure features, including certain changes in permitted speeds. AWS uses track mounted magnets which are detected by receivers fitted to trains. When a train passes over a magnet, the system on the train sounds a bell or chime, if approaching a signal displaying a green aspect, or a horn if approaching a signal displaying any other aspect. The system also sounds a horn if approaching a specified reduction in permissible speed. The driver must acknowledge the horn warning by pressing a button on the driving desk within a specified time, otherwise the system on the train will make an emergency brake application. The acknowledgement of a horn warning is shown on a visual indicator which changes to a yellow and black display known as a 'sunflower'.

32 TPWS was developed in the mid-1990s and implemented in accordance with the Railway Safety Regulations 1999 to automatically apply the train's brakes and reduce the risk arising from trains passing signals at danger. It is fitted at signals on passenger lines which protect certain conflicting movements. The system is also used to enforce reductions in permissible speed on approach to stop signals and speed restrictions and to intervene if trains approach buffer stops at too high a speed. TPWS is not designed to prevent incidents of speeding or signals passed at danger (SPADs); rather, it is designed to reduce the consequences of such incidents by slowing trains or, in the case of a SPAD, by stopping a train before it reaches the conflict point at a converging junction. The system is also not designed to fully protect all types of train at all speeds.

33 TPWS uses radio frequency transmitters (known as 'loops') fitted between the rails and receiving equipment on the train. At signals capable of showing a red aspect, a pair of loops is used in a configuration called a train stop system (TSS).

34 If the features of the layout mean that a TSS alone would not stop a train before the conflict point, then a second pair of loops can be placed at a specified distance on approach to the signal. These loops are known as an overspeed sensor system (OSS) and may also be fitted where there are significant reductions in permitted speed (that is, where permissible speed warning indicators are used). The two OSS loops in a pair are placed a set distance apart according to the speed at which an intervention is required at that location.

35 The OSS and TSS loops for signals are energised when the signal is displaying a red aspect, whereas loops for speed reductions are permanently energised. If a train passes over TSS loops when they are energised, the TPWS equipment on the train will demand an emergency brake application. For OSS loops, the brake demand depends on the train reaching the second loop in the pair before a specified time period has elapsed, thus indicating that the train's speed is higher than the 'set speed' for the TPWS installation. The driver receives a visual indication that the brake intervention has occurred and must acknowledge it as part of the process of resetting the system before continuing. Signals SY31 and SY29 are fitted with TSS loops; both signals and the 50 mph (80 km/h) permanent speed indicator are fitted with OSS loops.

Trains involved

36 On the day of the accident, train 1L53 was formed of a single three-carriage class 159 diesel multiple unit (DMU), number 159102. Although shorter formations are not unusual, this train service would normally have been formed of nine carriages. On the day of the accident the train length was reduced due to service disruption.

37 Train 1F30 was formed of two class 158 DMUs, numbers 158762 (leading) and 158763 (trailing). Each of these units comprised two carriages, forming a four-carriage train.

38 Class 158 and 159 trains are very similar and are constructed by welding aluminium extrusions together to form the bodyshells. The carriages which formed trains 1L53 and 1F30 were built between 1989 and 1992 by British Rail Engineering Limited in Derby.

39 The braking system fitted to class 158 and class 159 units decelerates the train by supplying air to brake cylinders mounted on the train's bogies. These brake cylinders apply friction pads to brake discs mounted on the wheelsets. A driver can apply three levels of braking in normal service. Step 1 brake provides the lowest level of braking, while step 3 (known as 'full service braking') provides the maximum braking effort. A driver can also make an emergency brake application. This applies the same level of retardation[3] as step 3 but uses a different control system to normal service braking so the train can still be braked in the event of a failure of that system.

40 Both trains involved in the accident were fitted with a wheel slide protection (WSP) system. Analogous to the anti-lock braking system in a car, the WSP system monitors the rotational speed of the train's wheelsets to determine if any have stopped rotating and are therefore sliding on the rail. If the WSP system detects that wheel slide is occurring, the system automatically reduces the brake force being applied to the sliding wheelsets until the system determines that they are no longer sliding.

41 The WSP system is designed to optimise the train's braking in conditions of low friction between the wheel and the rail, while also minimising the potential for the wheels to be damaged by sliding. The system can also increase the available friction (and hence the available brake force) by injecting sand from nozzles into the wheel/rail interface of some wheelsets. The sanding system is controlled electrically but uses the train's air system to blow sand into the wheel/rail interface. Sand is discharged automatically when the WSP system detects wheel slide in any brake step.

42 On class 159 units, such as that which formed train 1L53, sand is injected under both wheels of the third wheelset from the front of the train. A sander system is also provided on the rear carriage of the three-carriage train, but this is inhibited when the carriage is trailing. This means that only the nozzles on the front carriage of a three-carriage Class 159 unit will discharge sand. Drivers of class 159 units do not have a facility to manually operate the sanding system when the train is braking; a manual sand button is provided for use when the driver is applying traction power.

[3] More recent multiple unit passenger trains are fitted with enhanced emergency brakes, which apply a higher level of retardation than full service braking. The relevant standard does not require class 158 and class 159 trains to have this capability.

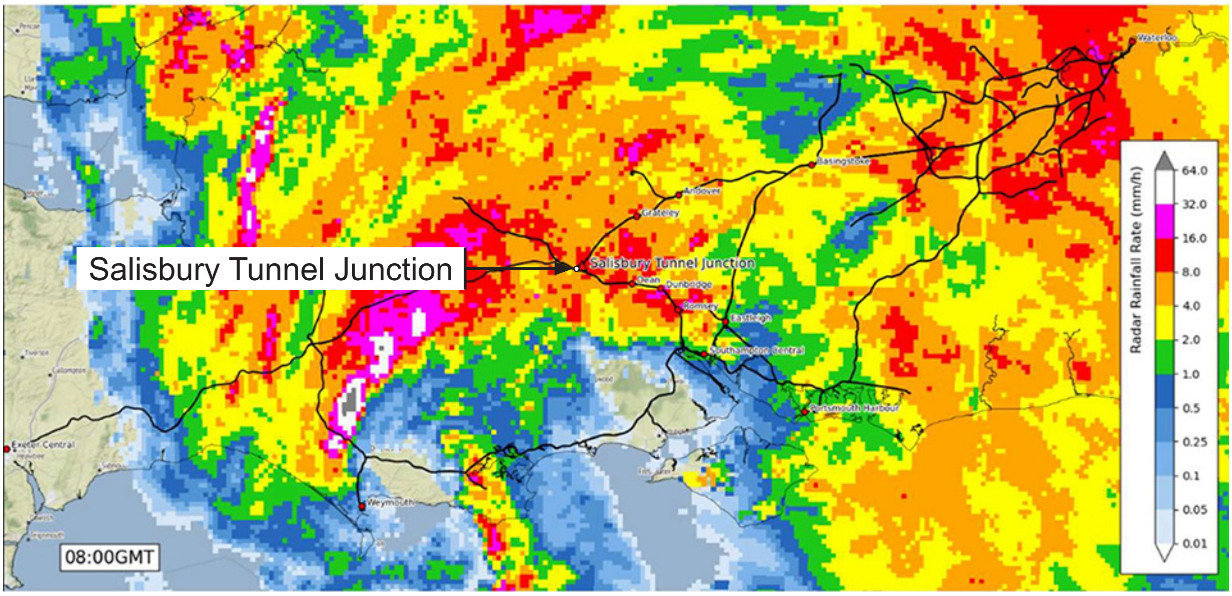
External circumstances

43 On the day of the accident, an unusual type of weather front passed through the Salisbury area, resulting in a decrease of air pressure concentrated on a particularly small region of around 30 km in diameter. This type of weather front, known as a mesoscale low-pressure event, is a relatively rare occurrence in the United Kingdom, with only ten similar events reported between 2009 and the date of the accident.

44 The mesoscale event in the Salisbury area on the morning of 31 October 2021 contributed to the worst recorded weather (in terms of combined wind and rainfall) data recorded by MetDesk and the Met Office so far that year (see paragraph 91 and figure 6).

45 The weather front brought localised strong winds and heavy rain to the area, causing major disruption to the Wessex route. Weather stations located near to Salisbury recorded maximum wind gusts of approximately 73 mph (117 km/h), peaking between 08:00 and 10:00 hrs. In the 12 hours preceding the accident, around 21 mm of rainfall was recorded, some 36% of the average monthly rainfall for the area.

46 After the weather front had passed, the area remained windy for the rest of the day with peak wind gusts of approximately 23 to 37 mph (37 to 60 km/h). Between 18:35 and 18:40 hrs, radar imagery showed a band of drizzle passing over the Up and Down Main lines in the area of Salisbury Tunnel Junction, just before the passage of train 1L53 (figure 6).



Time	05:00	06:00	07:00	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
Wind gust (mph)	30	33	34	35	49	55	36	34	35	34	-	32	-	-	-

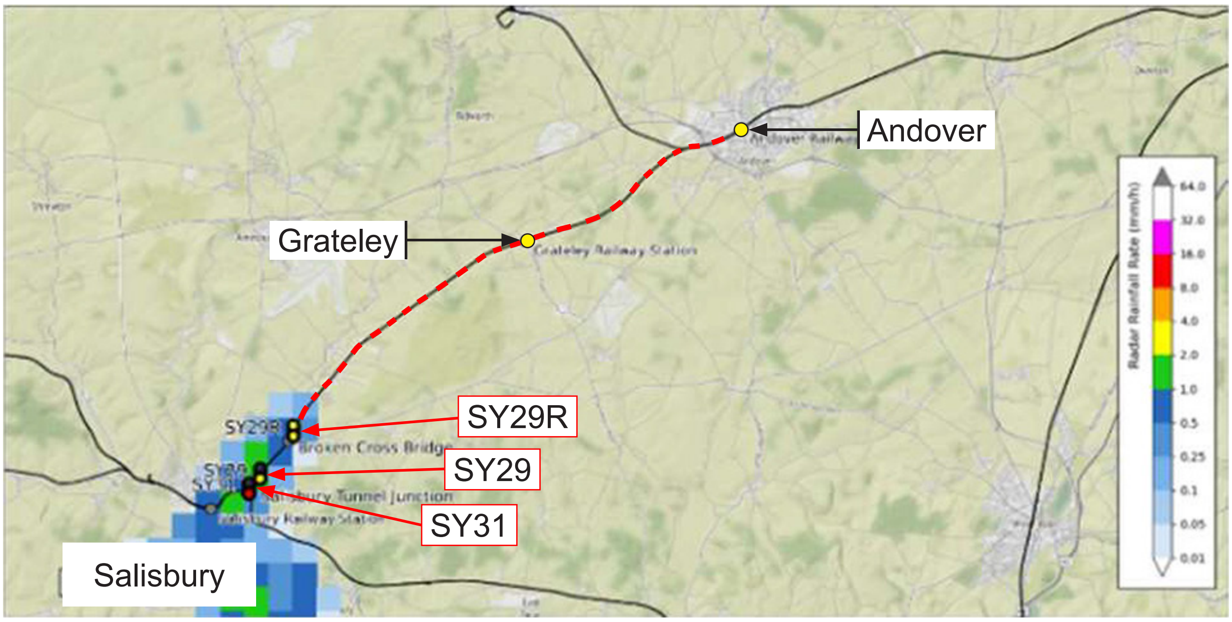


Figure 6: Met Office radar image (top) showing weather front for 31 October 2021 with wind gust speeds (middle) and macro radar image (bottom) showing the weather front passing over the Salisbury area and railway line (moving south-eastwards) between 18:35 and 18:40 hrs, in relation to the location of signals SY29R to SY31 (© Crown copyright 2023, the Met Office).

The sequence of events

Events preceding the accident

47 At 08:44 hrs on 31 October 2021, a train not involved in the accident, train 1L13, struck a tree[4] that had fallen onto the Down Main line at 80 miles 70 chains, around 250 metres west of Broken Cross bridge (80 miles 58 chains) (figure 5). The collision damaged the cab of the train, but no injuries were reported. The driver of 1L13 reported that they came to a stop in the vicinity of the AWS magnet for signal SY29, which was approximately 1350 metres beyond the fallen tree. On reporting this incident to the signaller, the driver stated that the train's braking was affected by "slipping" before colliding with the tree, but the conversation did not identify railhead contamination as a factor. There was no mobile operations manager (MOM)[5] available from Network Rail to attend the incident, so the train's driver and guard cut back the branches that were foul of the railway line, leaving the tree in the cess of the Down Main line (figure 7). The line was reopened at 10:44 hrs.

48 The incident near Broken Cross bridge was one of fifteen weather-related railway incidents that occurred on Network Rail's Wessex route that day. During the morning other incidents involving fallen trees and flooding caused significant disruption, including a tree blocking the Down Main line at the Salisbury (west) portal of Fisherton Tunnel.

Figure 7: The tree struck by train 1L13 (post-collision) on the Down Main line looking east towards London with Broken Cross bridge in the background.

[4] Another fallen tree was identified a short distance beyond signal SY29R, but this was examined and discounted as the tree involved in the collision with train 1L13.

[5] MOMs act as Network Rail's front-line response to any incidents affecting the safe and effective operation of the railway.

49 The driver of train 1L53 booked on for duty at Salisbury depot at 10:30 hrs. He was originally due to travel to Honiton to start his driving duties, but the effect of the severe weather conditions on the timetable led to several trains being cancelled. The driver therefore stayed in the mess room in Salisbury depot for the first part of his shift.

50 At around 14:50 hrs, the operational resource manager for SWR requested that the driver take train 1L52, the 15:27 hrs service from Salisbury to London Waterloo. Train 1L52 was formed of two class 159 DMUs, each of three carriages forming a six-carriage train.

51 The driver walked to the platform at Salisbury to meet the incoming train which would form train 1L52. Although there is witness evidence that he met another driver on the way who warned him of the adverse weather conditions, the driver stated that such a meeting did not occur. Later, while the driver was in the train's cab preparing train 1L52 for service to London, another driver contacted him from the train's rear cab using the cab-to-cab telephone. This was to warn him about poor rail adhesion on the Down Main line approaching Salisbury, which had been experienced by the driver of the incoming train from London Waterloo. The driver acknowledged the warning and thanked his colleague.

52 Train 1L52 departed from Salisbury at 15:27 hrs. Approaching Broken Cross bridge on the Up Main line towards London Waterloo, the driver, having been informed by his colleagues that there was a fallen tree in the vicinity, was looking for and noticed the remains of the fallen tree struck by train 1L13 on the adjacent Down Main line.

53 During the journey to London, the bad weather subsided, and the sun set at 16:42 hrs. The driver reported no conditions of low adhesion or any other difficulties with the train's braking or acceleration during this journey.

54 On arrival at London Waterloo, the driver changed trains, leaving train 1L52 and taking train 1L53 which departed from London Waterloo one minute late at 17:21 hrs. Soon after departure, the driver performed a routine running brake test[6] in the Vauxhall area, from a speed of 53 mph (85 km/h). The driver reported no issues with the braking capability of the train during the test. No further running brake tests were carried out during the journey and none were required by the SWR professional driving policy (see paragraph 269), unless the driver judged there was a problem with the train's braking.

55 The train called at Clapham Junction and Woking, where it departed six minutes late due to being held at a signal. The train then stopped at Basingstoke and Andover, departing Andover six minutes late at 18:30 hrs.

56 It was dark during the journey from London Waterloo and weather conditions were dry. The driver reported that he did not experience any WSP activity nor any instances of low adhesion that affected the train's ability to slow, stop or accelerate at station stops during the journey. Between 18:35 and 18:40 hrs a band of drizzle moved south-eastwards over the Up and Down Main lines in the Middle Wallop area, near Salisbury (paragraph 46). The drizzle ceased in this area before train 1L53 approached it.

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[6] Running brake tests are required to test the effectiveness of the train's brakes and are undertaken in accordance with the Rule Book GERT8000 Module TW1, 'Preparation and Movement of Trains' (issue 16, March 2021).

57 At 18:41:09 hrs, approximately 1 minute 47 seconds before the accident, the OTDR from train 1L53 recorded that the traction power had been shut off. The train then coasted[7] down the prevailing 1 in 169 gradient towards signal SY29R (figures 34 and 35).

58 Ten seconds later, OTDR data showed that the driver acknowledged the AWS warning horn for signal SY29R. Signalling data and forward-facing closed-circuit television (FFCCTV) showed that this signal was displaying a double yellow aspect. This was because signal SY29 was displaying a single yellow aspect, and signal SY31 was displaying a red aspect.

59 The driver approached Broken Cross bridge at about 18:41:36 hrs with the train still coasting. The driver stated that Broken Cross bridge was the point where he would normally start braking in anticipation of stopping at signal SY31. However, because he felt that there was a potential for low adhesion conditions at the location of the fallen tree, he decided to delay braking and use the fallen tree and associated debris as the marker point to start braking (figure 8). The driver believed that this would still leave sufficient time and distance to bring the train to a stand before reaching signal SY31.

Figure 8: (left) Tree that was struck by train 1L13 (branches had been cut back by the train driver and guard) and later observed by the driver of train 1L53 (when driving train 1L52 on the Up line to London Waterloo) and (right) enhanced image taken from train 1L53 FFCCTV system.

Events during the accident

60 Around 18:41:42 hrs, train 1L53 coasted past the location of the fallen tree and debris (figure 7) at a speed of 89 mph (143 km/h). Eight seconds later, at 18:41:50 hrs, the driver acknowledged the AWS warning horn associated with the warning sign for the approaching 50 mph (80 km/h) speed restriction.

61 At 18:42:02 hrs, with the train travelling at 86 mph (138 km/h) and around 1,560 metres beyond signal SY29R, the driver, having not noticed the fallen tree, applied the brakes. At this point, the train was on a descending gradient of 1 in 169, approximately 780 metres on approach to signal SY29, and approximately 1,560 metres on approach to signal SY31.

[7] Coasting is a state of train movement in which the driver is not braking or applying traction power.

62 Evidence from the train's OTDR data shows that the driver initially selected brake step 1, followed almost immediately by brake step 2. When the driver applied the brakes, he stated that he immediately felt and observed that something was wrong. The driver stated that the feeling 'under his seat' indicated that the train's wheels were sliding.

63 The driver realised that the train's speed was not reducing as he expected. Six seconds after his initial brake application, at 18:42:08 hrs, the driver made a step 3 (full service) brake application. This was followed a further six seconds later by the driver making an emergency brake application.

64 Equipment fitted to the train recorded that the WSP system was active from the start of braking and throughout the various brake applications, and this would have demanded the sanding system to discharge sand onto the railhead. However, this had a limited effect on reducing the speed of the train (figures 34 to 36).

65 At 18:42:24 hrs, train 1L53 passed signal SY29 (displaying a single yellow aspect) at approximately 77 mph (124 km/h).

66 At 18:42:42 hrs, the train's TPWS detected that the train was travelling above the set speed of 34.5 mph (55.5 km/h) for the OSS of the approaching signal SY31, which was showing a red aspect. The TPWS therefore commanded an emergency brake application. However, this had no additional effect as the driver had already made an emergency brake application (paragraphs 34 and 35).

67 At 18:42:49 hrs, train 1L53 passed signal SY31 and approached Salisbury Tunnel Junction. About 40 seconds earlier, GWR train 1F27 had passed over the junction on the Up Dean line on its journey from Salisbury to Southampton. Meanwhile, train 1F30 was approaching the junction on the Down Dean line heading towards Salisbury.

68 The driver of 1L53 saw train 1F30 appear from the left and move into the path of his train. Believing there was little he could now do to prevent a collision, he got out of his seat with the intention of exiting the cab into the saloon. However, in doing so, he tripped over his bag, and fell onto the floor just before the collision occurred (figure 9).

69 As train 1F30 was entering Fisherton Tunnel, train 1L53 collided with its right-hand side, near the front of the fourth carriage (figure 10). Evidence from the OTDR on train 1L53 suggests that the collision occurred at 18:42:57 hrs, with train 1L53 travelling at a speed of approximately 52 mph (84 km/h). The OTDR on train 1F30 recorded its speed as being around 20 mph (32 km/h) at the time of the collision.

70 The 32 mph (51 km/h) speed differential between the two trains meant that train 1L53 travelled forwards in heavy contact along the right-hand side of the fourth carriage of train 1F30. It then continued along the right-hand side of the third carriage, with the leading left-hand edge of the cab of train 1L53 embedding itself in the front end of this carriage (figure 11).

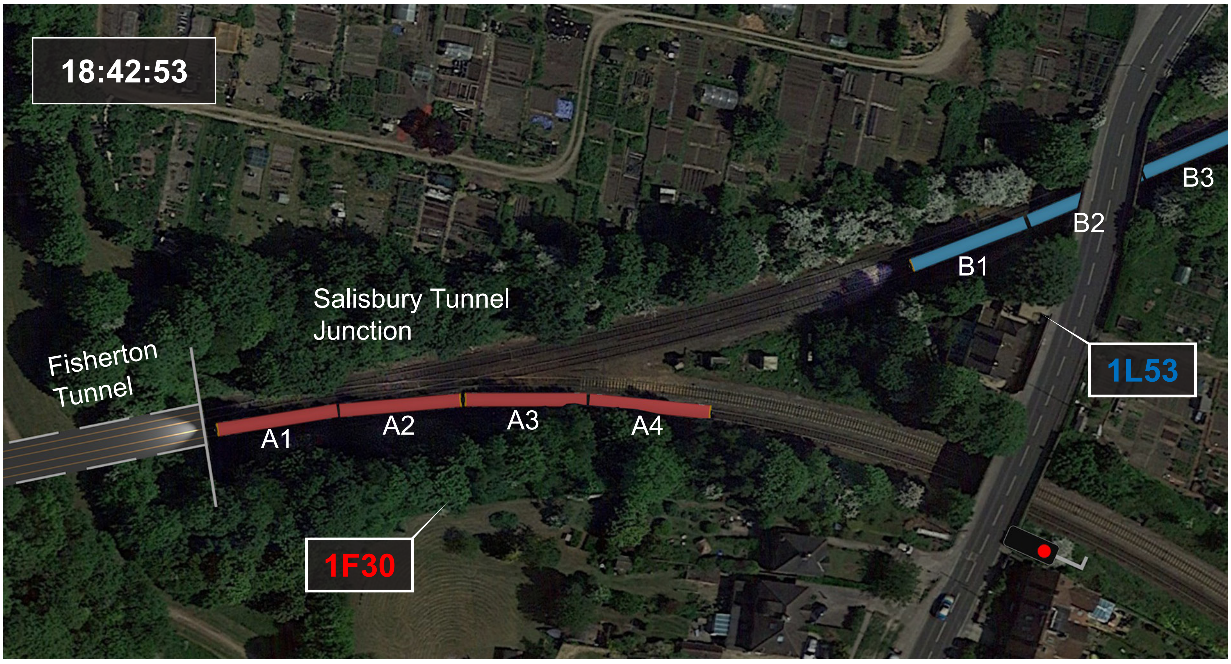

Figure 9. Diagram showing train 1L53 (carriages marked as B1 to B3) and train 1F30 (carriages marked as A1 to A4) immediately before the collision.

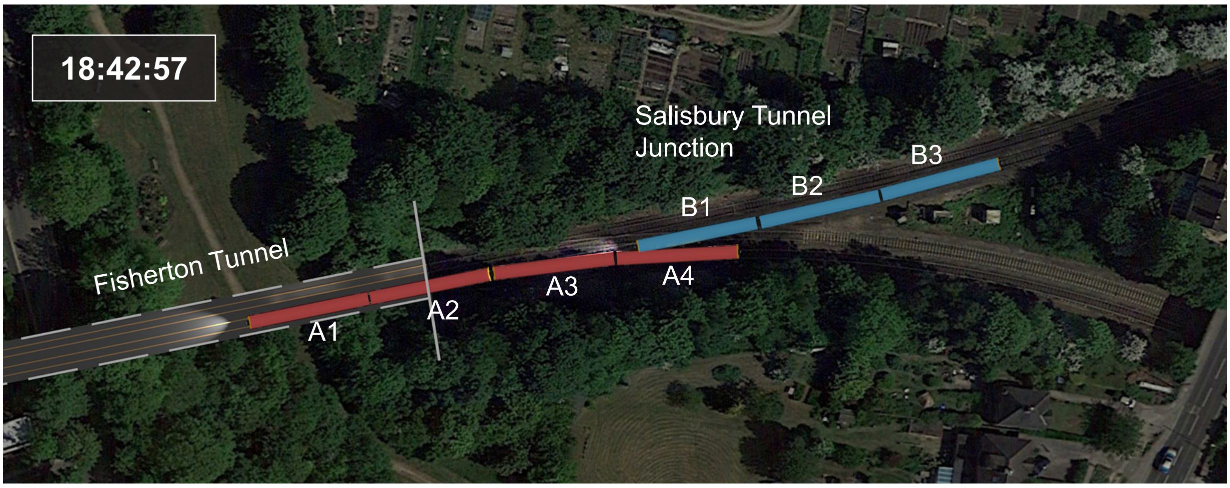

Figure 10: Diagram showing train 1L53 colliding with train 1F30.

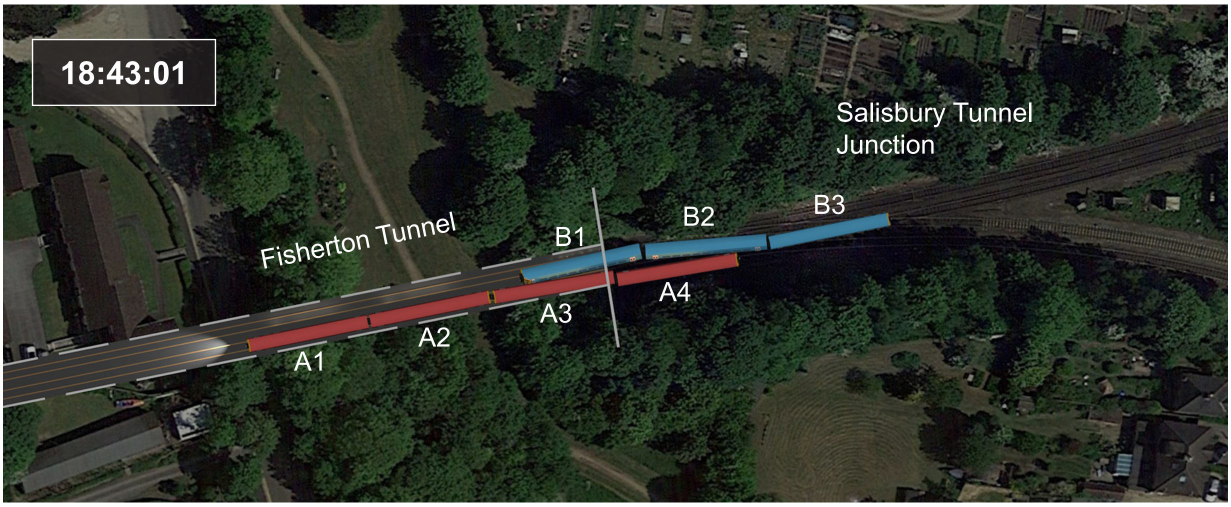

Figure 11: Diagram showing trains 1L53 and 1F30 derailing into Fisherton Tunnel.

71 The fourth carriage of train 1F30 was displaced to the left by the impact, resulting in its leading left corner coming into heavy contact with the facing portal wall of Fisherton Tunnel (figure 12). This caused a failure of the coupling between the second and third carriages of train 1F30, opening a gap of 23.8 metres between the two halves of the train. At this time, passengers intending to leave train 1F30 at Salisbury station were still seated, and no passengers were standing in the vestibule area where the train parted.

Figure 12: Impact mark from carriage A4 on facing portal wall of Fisherton Tunnel. Vestibule of A3 is visible and carriage A4 has been removed.

72 Both trains travelled into Fisherton Tunnel, with the tunnel walls acting to keep the carriages upright. The rear two carriages of train 1F30 and all carriages of train 1L53 derailed, with the cab of train 1L53 being severely damaged. The front carriage of train 1L53 came to rest adjacent to the leading end cab of the third carriage of train 1F30 (figures 13 and 14).

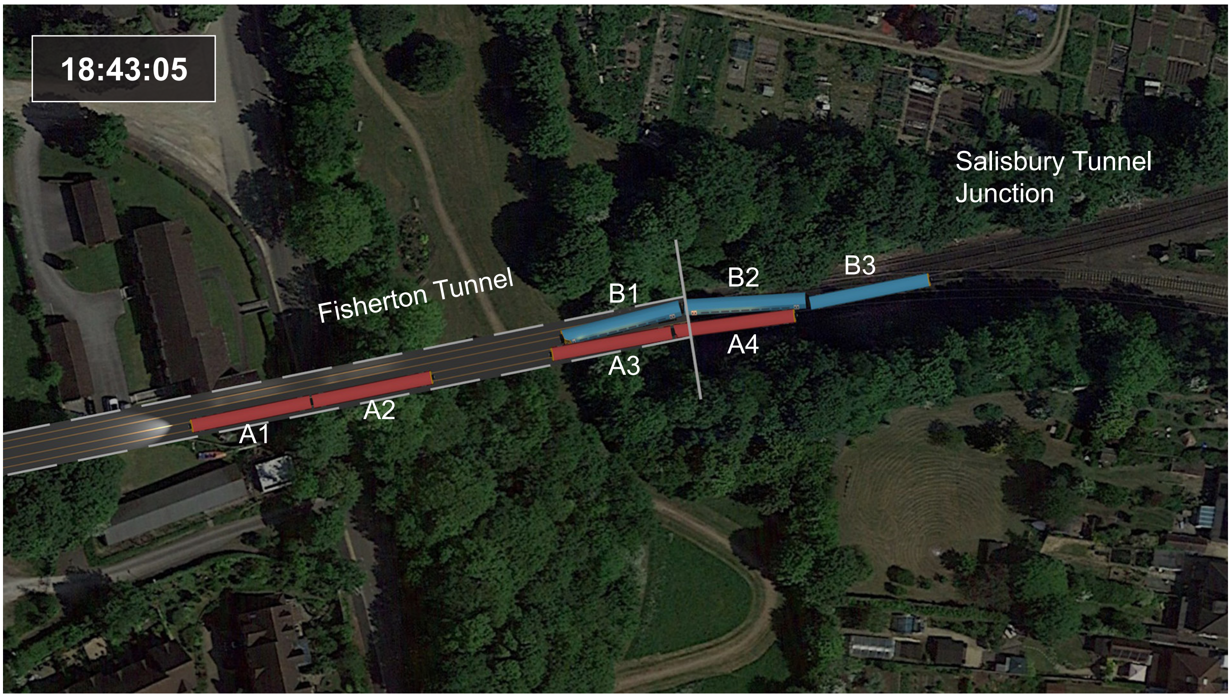

Figure 13: Diagram showing carriages A2 and A3 separated within Fisherton Tunnel.

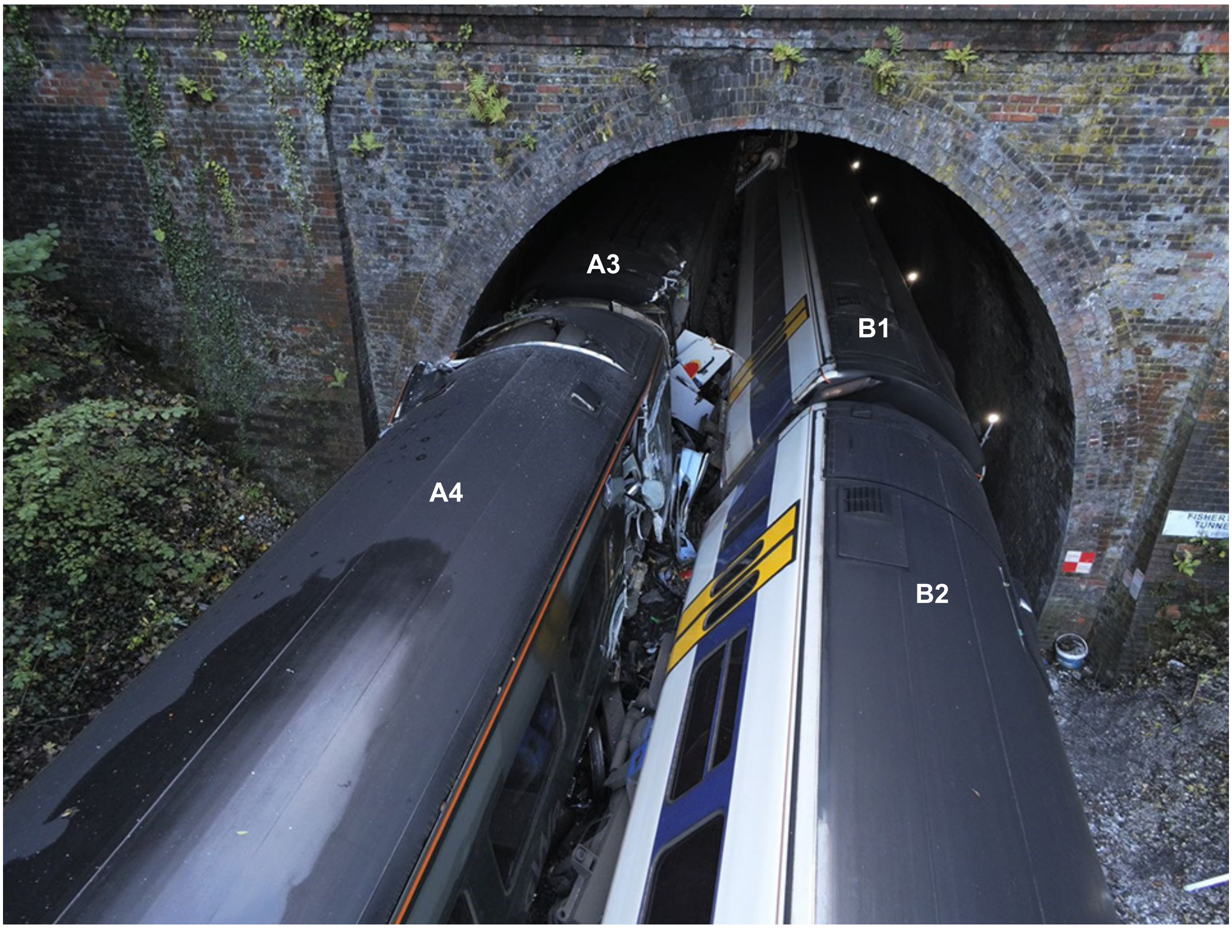

Figure 14: View from London portal of Fisherton Tunnel showing the rear carriages of train 1F30 (A3 and A4) and front carriages of train 1L53 (B1 and B2).

Events following the accident

73 The driver of train 1L53 was injured in the collision and was trapped in the heavily damaged cab (figure 15). At around 18:46 hrs, the guard on train 1L53 attempted to contact the driver but was unsuccessful in doing so. The guard then tried to make a railway emergency call to the signaller using the GSM-R[8] train radio in the rear cab, but this again was unsuccessful. They then used their mobile phone to contact the emergency services and provided information from 18:45 until 19:15 hrs when they were met by responding fire and rescue personnel.

Figure 15: View from within Fisherton Tunnel showing the front cab of train 1L53 (B1) and carriage A3, having separated from carriage A2, of train 1F30. Parts of the driving cab of train 1L53 have been cut away by the emergency services to release the trapped driver.

74 The driver of train 1F30 felt the impact of the collision and immediately made a GSM-R railway emergency call, reporting to the signaller at Salisbury that they believed their train had derailed. In response, the signaller placed all signals in the area to red.

75 On completion of the emergency call, the driver of train 1F30 left their cab to investigate what had happened. They walked back through the train and found the rear two carriages had become detached. Realising then that another train may have collided with train 1F30, they returned to the cab and made another railway emergency call to the signaller to update them with this information.

[8] Global System for Mobile Communications – Railway, a dedicated telecommunications network for the national rail network. The systems on both trains were found to be working correctly.

76 From 18:46 hrs onwards, a number of calls were made to the WICC at Basingstoke. Due to the volume of calls and the chaotic nature of the scene in the tunnel, around 17 minutes elapsed following the collision before staff at the WICC made contact with the guard of train 1L53 and established that it had also been involved in the accident.

77 Both GWR and SWR mobilised ‘on call’ teams to the accident site. As members of train crew at Salisbury station and depot became aware of the accident, they also went on foot to the scene to offer assistance to passengers. On arrival, they found passengers were already trying to evacuate from train 1F30 via a window that had been broken (see paragraph 291).

78 Network Rail and SWR staff from Salisbury station arrived at the scene and, at 19:06 hrs, Network Rail declared a major incident.[9] Wiltshire Police and Dorset and Wiltshire Fire and Rescue Service arrived at the scene at 19:10 hrs and confirmed the declaration of a major incident with the other agencies attending (such as the South Western Ambulance Service and British Transport Police). By 19:56 hrs the fire and rescue service had reported that, with the exception of the train driver of train 1L53, all passengers and staff had been evacuated from the trains and had exited from the tunnel. At 20:45 hrs, the fire and rescue service reported that the evacuation was complete.

79 The damage to the rail carriages prevented the movement of passengers between some carriages. Consequently, it was necessary to evacuate passengers simultaneously from both the front and rear of the trains involved. Some passengers, predominantly those in the leading three carriages of train 1F30, were evacuated to Salisbury station. Passengers in the remaining carriages were evacuated from the rear of the trains and walked trackside to a railway access gate.

80 RAIB was notified of the accident at 18:53 hrs and immediately deployed a team of inspectors, who arrived on site at 21:20 hrs. RAIB handed the accident site back to the railway in stages, with the final areas being released on 7 November 2021. Repairs and reinstatement of the track and signalling were completed on 15 November 2021, with services through Salisbury Tunnel Junction resuming on 16 November 2021.

[9] An event or situation with a range of serious consequences which requires special arrangements to be implemented by one or more emergency responder organisation.

Analysis

Background information

Wheel/rail adhesion

81 Because trains rely on friction between wheel and rail to stop, the level of wheel/rail adhesion available is critical to the rate at which a train can decelerate. Research[10] indicates that the level of adhesion available is mostly affected by railhead contamination and moisture on the railhead.

82 Railhead contamination can be caused by a number of things, but the most common cause is leaves falling onto the railhead and then being compressed by the wheels of trains rolling over the material, building different layers and an increased thickness of contamination. The layers of leaf fall are created and bonded as a result of chemical reactions occurring during the rolling and sliding of wheels over the contamination. The level of adhesion between a train's wheel and the railhead is normally expressed as a coefficient of friction. The lower the value of the coefficient of friction, the lower the adhesion between wheel and rail (table 1). Adhesion levels can vary considerably over relatively short distances and timescales.

Adhesion level	Typical coefficient of friction	Description
High	> 0.15	Clean rail wet or dry
Medium	0.10 to 0.15	Damp rails with some contamination
Low	0.05 to 0.10	Typical autumn mornings due to dew / dampness often combined with light overnight rust
Very low	<0.05	Severe rail contamination often due to leaves but sometimes other pollution

Table 1: Range of railhead adhesion on the rail network as defined by the Adhesion Working Group.

83 Research[11] undertaken on behalf of the industry's Adhesion Working Group (AWG) led to it publishing guidance for the industry in 2006, most recently updated in 2018.[12] This provides the following comment on low adhesion conditions:

> *'The rail surface and the wheel treads can become coated with a range of contaminants. The worst of these are crushed leaves, which, when combined with moisture particularly in the form of dew or condensation, reduces the adhesion level. For a train on dry rails adhesion is typically around 0.25, on wet rails it is around 0.15, but on damp leaf (layers) it can be as low as 0.015. Rails with damp leaves (layers) significantly constrain the rate of braking.'*

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[10] Rail Safety and Standards Board (RSSB) project T354 'The characteristics of railhead leaf contamination' https://www.rssb.co.uk/research-catalogue/CatalogueItem/T354'.

[11] Tests undertaken by ARUP on behalf of Network Rail in 2006 'Autumn 2006 measurement Trials'.

[12] AWG Manual, Sixth Edition, January 2006 amended 2018. The Adhesion Working Group has since evolved into the Seasonal Challenge Steering Group (SCSG).

84 Guidance on the thickness and levels of contamination (figure 24) and action to be taken are included within Network Rail standard NR/L2/OPS/045-4.07, 'National Operating Procedure, Section 07 Railhead contamination levels' (issue 2, December 2019).

85 Leaf layer thicknesses will typically measure up to 0.2 mm but can be thicker when the base layers become bonded to the rail. Train wheels under acceleration and braking can result in the contamination 'creeping' (a series of very small horizontal movements), which can further increase the thickness of any railhead contamination present at certain points. Sliding train wheels, in contrast, may have the opposite effect and result in layers being removed.

86 Post-accident examination of the Up and Down Main lines between signal SY29R and the accident site showed that, although the topography and tree species were very similar in number and density either side of the railway, the levels of railhead contamination varied, with contamination on the Down line being medium to heavy at locations where it was only minimal on the adjacent Up line. This demonstrates how localised changes in wheel/rail adhesion conditions can be.

87 The speed at which layers of contamination build up is dependent on a number of factors, including the number of trains that have passed over the location since the last treatment, train braking and the leaf fall within a given period. The rate of leaf fall is in turn affected by the environment, meteorological conditions, topography (such as cuttings and embankments, figure 16) and tree species. However, the relationship between the rate of build-up of contamination and these factors remains largely undefined.

88 For the purposes of managing wheel/rail adhesion, Network Rail considers the autumn leaf fall season to run from 1 October to 13 December each year. While the rate of leaf fall can vary depending on weather conditions throughout the year, the rate of fall normally begins to accelerate in the middle of October with the 'peak leaf fall' period occurring from around 22 October through to around 31 October. A further acceleration of leaf fall can also occur from around 31 October through to around 24 November, when around 40 to 60% of all remaining leaves normally fall from trees, depending on the species involved.

89 The cross-industry Adhesion Research Group (ARG) promotes understanding of wheel/rail adhesion, train detection and related topics, and ensures a common and system-wide approach to these issues. It acts as a sponsor for research projects and co-operates with the Seasonal Challenge Steering Group and Seasonal Challenge Communications Group to implement research on the running railway.

90 RSSB in collaboration with the Adhesion Research Group developed an adhesion research programme called ADHERE. The programme has been running since 2018 and continues to provide research to improve the rail industry's knowledge, and management, of low adhesion conditions. The programme includes workstreams investigating: the modelling of low adhesion and braking; the effectiveness of rail cleaning activities and treatments; driver behaviours; current train-borne technologies, including double variable rate sanding (DVRS, see paragraph 220) and magnetic track brakes; and adhesion forecasting and observational capabilities to improve real-time decision-making.

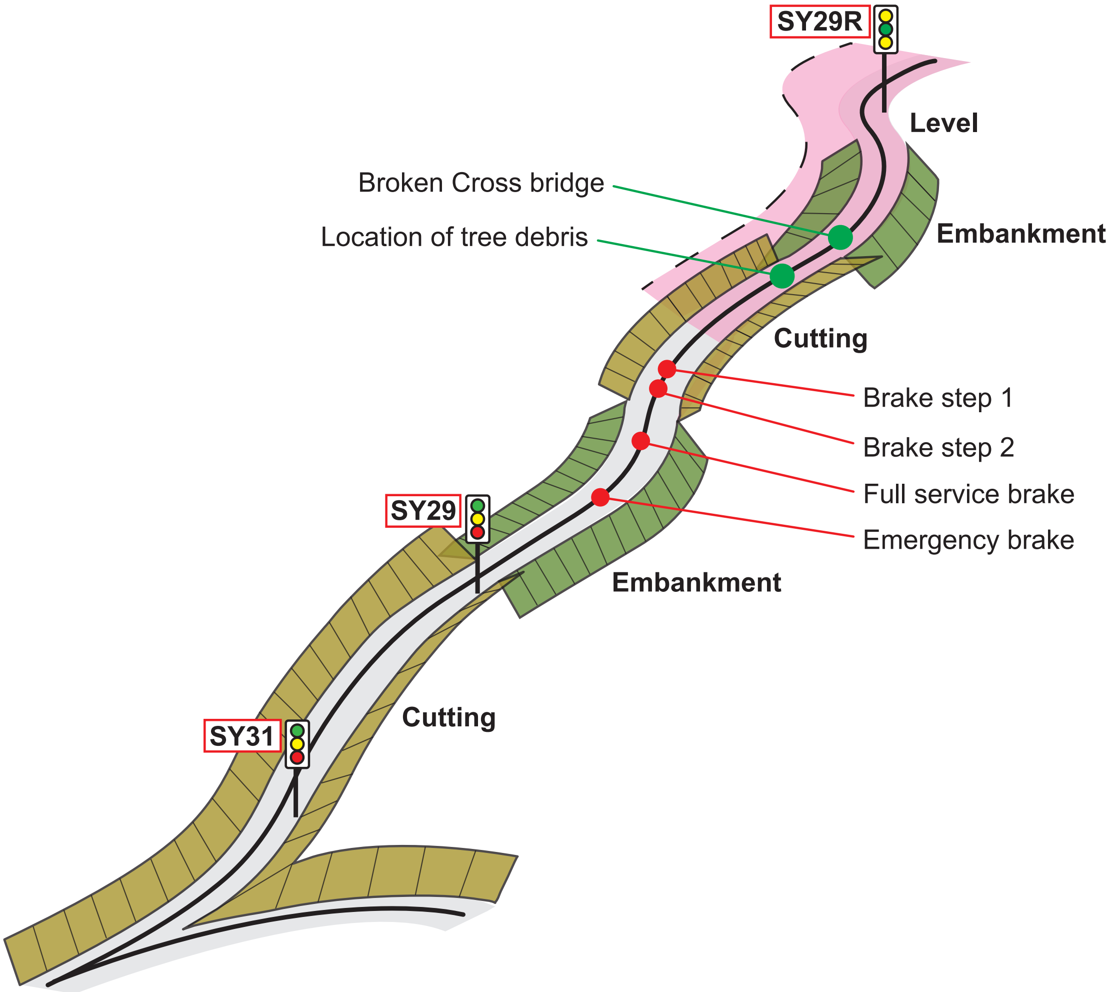

Figure 16: Topography data showing the embankment/cutting profiles, including the previously classified high risk of low adhesion site (pink shaded area - see paragraph 143), the location of Broken Cross bridge, tree/associated debris (green dots), the braking points of train 1L53 (red dots) and signals.

Weather and forecasting

91 Network Rail has a contract with a national weather forecast provider, MetDesk Ltd (MetDesk). MetDesk sends weekly and daily weather and adhesion forecasts to each integrated control centre, including the WICC (figures 18). Additional information is also made available via the Network Rail Weather Service website.

92 Network Rail's Wessex route also receives a daily weather and low adhesion forecast (figures 17 and 23) from the Meteorological Office (Met Office). These provide a forecast of railhead adhesion and damp rail risk for sections of line between individual stations within the Wessex route. They are intended to assist Network Rail operations staff in planning any necessary low adhesion risk mitigation, for instance, additional MPV railhead treatment runs or MOM inspections. The adhesion forecast considers site-specific forecasts of leaf fall (from the Met Office leaf fall model), rainfall, rail temperature and dew point temperatures to forecast low adhesion. The low adhesion forecasts are also shared with SWR during the leaf fall season.

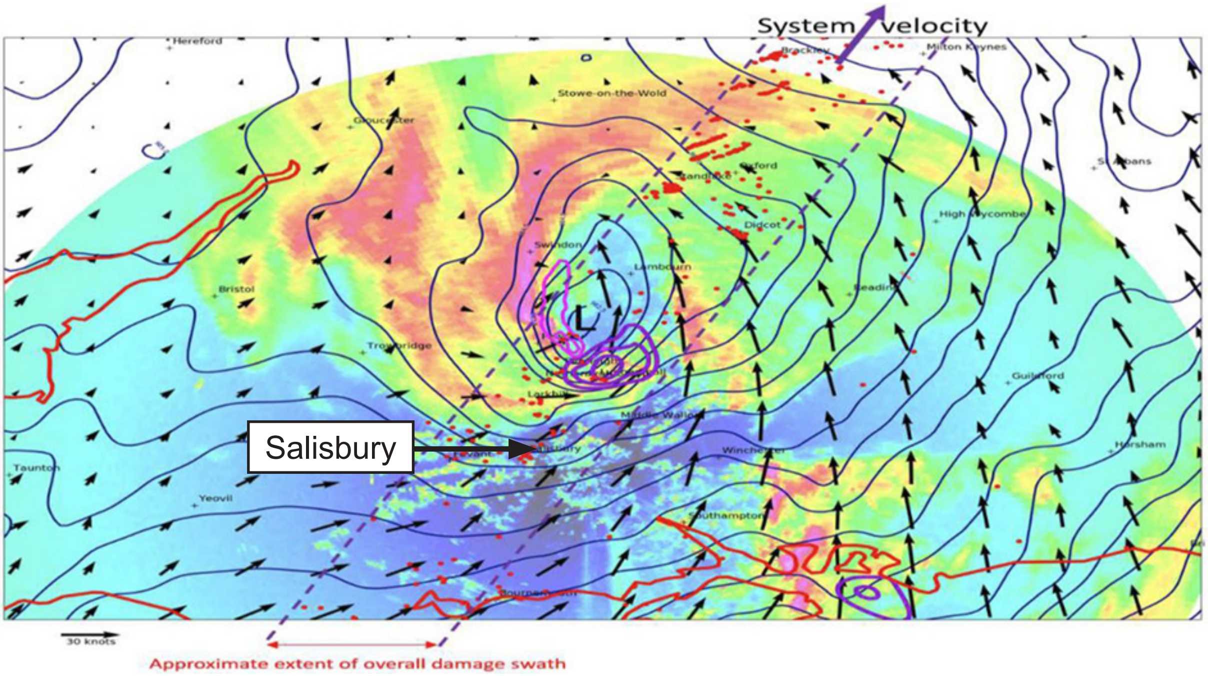

Figure 17: Image of the mesoscale weather front for 31/10/2021 (© Crown copyright 2023 The Met Office).

Summary Hazards - Wessex Outer (Wessex)

Day (0600 to 0600)	Wind		Heavy Rain		Snow		Frost		Min Temp Morn (06-11)	Max Temp (06-18)	Min Temp (18-06)	Temp Range		Ice Day		Lightning Risk		Freezing Fog	
	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.				Hazard	Conf.	Hazard	Conf.	Hazard	Conf.	Hazard	Conf.
Sun	Adverse	Medium	Adverse	Medium		High		High	11.0	15.0	6.0		High		High	Aware	Low		High
Mon		Low		Medium		High	Aware	Low	6.0	13.5	0.0		High		High	Aware	Low		High
Tue		High		High		High	Aware	Low	1.0	12.5	-0.5		Medium		High	Aware	Low		High
Wed		High		High		High	Aware	Low	-0.5	12.0	0.0		Low		High		High		High
Thu		High		High		High		Medium	0.5	11.5	0.5		High		High		High		High

Wessex	31/10	01/11	02/11	03/11	04/11	31/10	01/11	02/11	03/11	04/11	31/10	01/11	02/11	03/11	04/11	31/10	01/11	02/11	03/11	04/11
Route average	8	7	5	5	5	6	7	5	4	4	65.4	63.3	62.8	62.1	61.4	5.0	4.9	3.7	2.4	2.1
Wessex Outer	8	7	5	5	5	7	7	5	5	4	65.2	63.2	62.7	62.0	61.3	5.2	4.9	3.6	2.3	2.1
Wessex Inner	8	7	5	5	5	6	7	5	5	5	65.5	63.4	62.9	62.2	61.5	4.8	5.0	3.8	2.5	2.1
London Southwest	8	7	6	5	5	6	5	5	4	4	65.5	63.3	62.8	62.1	61.4	4.6	4.5	3.7	2.5	2.2

Figure 18: (top) Extract from the MetDesk forecast showing an amber, adverse (circled) warning for wind and heavy rain on Sunday 31 October 2021; and (bottom) five-day adhesion forecast for Wessex route (outer) showing adhesion risk score seven (circled – see also figure 19 Adhesion forecast showing the categories, with a score of 7 being a ‘red day’). The leaf fall density percentage is also shown.[13]

93 Weather conditions are forecast using a scale from ‘normal’ through ’adverse’ to ’extreme’. This scale is applied to flooding, rain, wind and snow. Network Rail’s Wessex route operations control uses this forecast to liaise with the MDU and asset managers to consider appropriate mitigations and the preparation and provision of resources to undertake any mitigation activities identified as necessary. If thresholds for certain weather-related trigger points are passed, Wessex route’s autumn working arrangements document (see paragraph 97) requires an extreme weather action team/teleconference (EWAT) to be convened.

[13] Leaf fall density indicates the number of leaves (area and species) that are still on the trees. The Met Desk data shows 65.2% (green box - circled) of leaves were still present and the leaf fall ‘drop’ was around two weeks behind schedule for data gathered since 2016.

94 The purpose of the EWAT is to assess the potential impact of extreme weather on the infrastructure and to determine mitigation, contingency plans and how actions and decisions will be communicated within Network Rail and the associated train operating companies. The forecast predicted ‘adverse’ weather conditions for 31 October 2021[14] (figure 18). Network Rail standard NR/L2/OPS/021, 'Weather - managing operational risks', appendix (A), shows the hazards and consequences of high wind speeds to be fallen trees and leaf fall leading to railhead contamination that could result in low adhesion, loss of track circuit detection from wrong side failures and a category A SPAD. However, the weather forecast and the actual conditions on the day did not reach the thresholds for an EWAT to be convened, resulting in the potential hazards not being considered (see paragraph 252).

95 MetDesk’s data sheets are usually issued between 02:00 and 03:00 hrs for the day ahead. Railhead adhesion forecasts are based on rainfall, leaf fall, dew point and rail temperatures. The adhesion forecast uses an adhesion risk score which runs between 0 (good) and 10 (very poor). These scores are then categorised into five colour-coded levels, from ‘good’ adhesion (green) progressing through ‘poor’ (red) where there is a high risk of leaf fall and disruption to the network if the railhead is not treated. ‘Very poor’ adhesion’ (black) is the most severe category, with very high contamination likely due to leaf fall and damp conditions with a very high risk of disruption to the rail network (figure 19).

96 Network Rail shares information on the adhesion conditions with SWR. SWR in turn posts notices at depots for its drivers indicating the expected weather and adhesion levels, using the same colour-coded index (see paragraph 182).

Operations

97 Network Rail operations standard NR/L3/OPS/021/01, ‘Autumn Management’ (issue 1, June 2019) outlines how Network Rail, in collaboration with train operators, prepares, manages and responds to the risks arising from autumn weather. The responsibility for developing and implementing the ‘route specific’ process lies with the SDS for each Network Rail route. Wessex route introduced the post in 2014 (although roles with similar functions existed from around 2004).[15] From March each year, the SDS develops the Wessex route autumn working arrangements (designated as NR/L3/OPS/021/01/Wessex). This is based on NR/L3/OPS/021/01 and is prepared against the timeframe specified in Network Rail standard NR/L3/OPS/021/11 Module 11, ‘Seasonal calendars’ (issue 1, September 2020) (figure 20).

[14] Network Rail standard NR/L2/OPS/021 provides a definition for ‘adverse’ or amber status as weather conditions which, while not extreme, are known to be challenging to reliable operations. However, with effective maintenance, timely delivery of seasonal preparation and robust deployment of mitigation measures, the full timetable can be delivered with acceptable reliability.

[15] Witness evidence shows a role known as a seasonal manager/planner was introduced in 2004. In 2012 the Wessex route created a new performance team, and the role of seasonal planning and strategy manager was introduced. In 2014 the title was changed to performance improvement specialist and in 2018 the title of the role became seasons delivery specialist (SDS).

Adhesion Index	Description
0 to 2	**Good adhesion conditions expected** Leaf contamination unlikely except in very prone locations. Rails generally dry or briefly damp.
3	**Wet railhead expected** Rails damp or wet, generally devoid of leaf contamination away from prone spots, but sufficient to reduce adhesion between the wheel and rail, potentially leading to wheel slippage.
4 to 5	**Moderate adhesion conditions** Moderate leaf fall risk with dry conditions. Slight contamination with damp rail. Some disruption to the network could be expected, especially in cuttings or densely vegetated areas.
6 to 8	**Poor adhesion conditions** High leaf fall risk with dry conditions. moderate leaf fall contamination with damp rail conditions. Disruption to the network likely if treatment not completed.
9 to 10	**Very poor adhesion to extreme leaf fall conditions** Very high contamination of the railhead due to leaf fall. High to very high contamination of the railhead due to leaf fall and damp rail conditions. Very high risk of disruption to the network

Figure 19: Replication of Network Rail's Adhesion Index forecast table (courtesy of Network Rail).

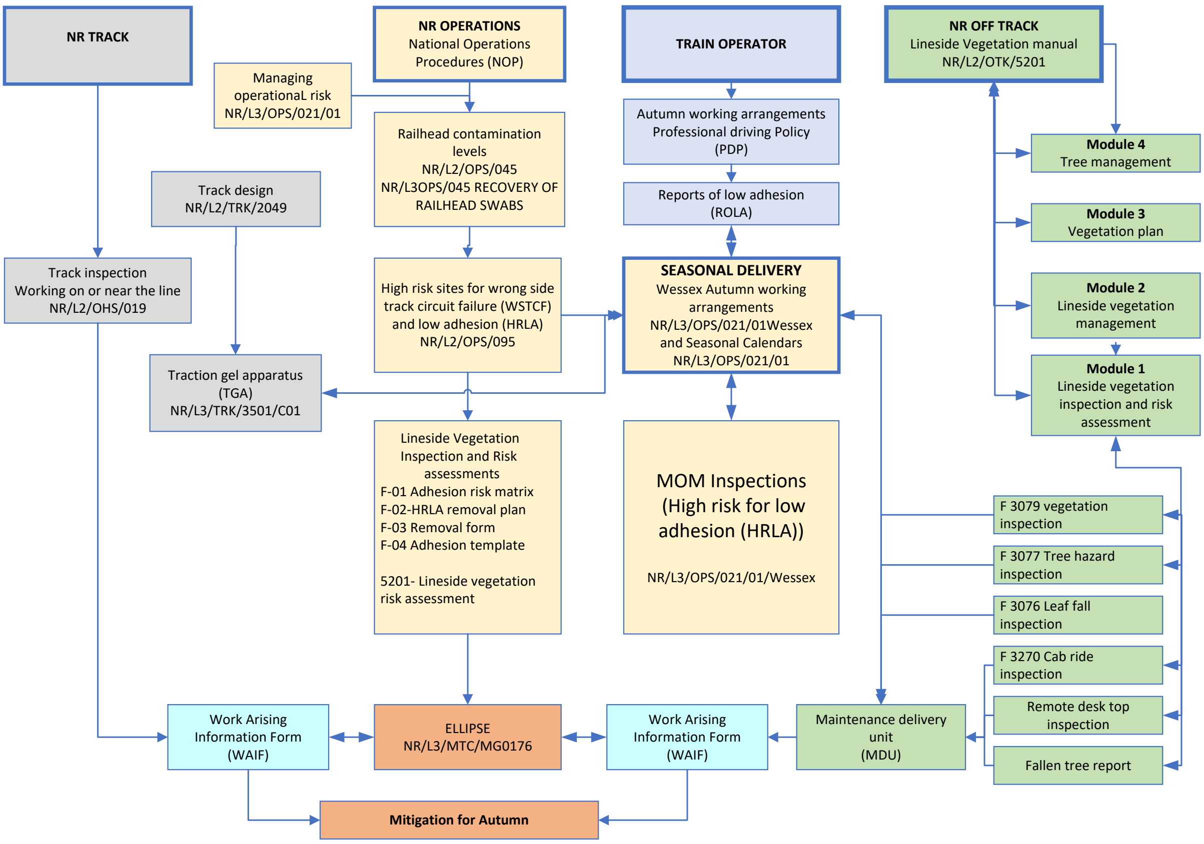

Figure 20: Diagram showing relationships between the various departments within Network Rail and the standards applicable to managing, preparing and collaborating internally and externally with the train operator in planning and responding to autumn and low adhesion incidents.

98 In August 2021, the Wessex route SDS presented and discussed the proposed arrangements for autumn 2021 with other Network Rail departments in the route and with SWR.[16] SWR then incorporated some of the relevant details from the proposed Wessex autumn working arrangements within its autumn train driver briefing document, which was issued in September 2021.

99 Network Rail's Wessex route published and circulated its finalised autumn working arrangements document on 15 September 2021. This document identified high risk of low adhesion (HRLA) sites and outlined how the route would take action regarding low adhesion across its network. The options available in the document for the SDS to mitigate the risk from railhead contamination were to arrange for railhead treatment through deployment of MPVs, install static lineside traction gel applicators (TGAs), or arrange for inspections and manual railhead treatment by a MOM.

Railhead treatment

100 The objective of railhead treatment is to remove crushed leaf film or other contaminants from the railhead using high-pressure water jetting with the option, once the railhead is clean, of applying a sand-based gel known as an adhesion modifier. This is intended to help break up any remaining leaf film on the railhead and to raise the adhesion level by introducing a friction improver at the wheel/rail interface.

101 Railhead treatment is delivered across longer stretches of track by MPVs and/or railhead treatment trains (RHTTs). MPVs have less capacity than RHTTs and generally need to return to the depot after each eight-hour shift. Network Rail's Wessex route only uses MPVs. In 2021, the route had six MPVs which ran over nine circuits, covering more than 750 route miles.

102 Network Rail's Wessex route's autumn working arrangements document sets out an aspiration for all routes to be covered by railhead treatment once every 24 hours throughout the autumn. During autumn 2021, Wessex route scheduled its MPVs over the circuits twice each day, once in the morning and once in the afternoon/evening, from Monday to Friday. Due to track access restrictions at weekends, caused, for example, by engineering possessions, only one run was scheduled per circuit on a Saturday and Sunday. This scheduling practice is common nationally across Network Rail during weekends.

103 As well as the scheduled circuits, additional runs of the MPV can be made as needed following requests from the SDS, signaller or other staff at the WICC (see paragraph 110). Such 'work as required' requests usually follow reports of low adhesion by train drivers or MOMs.

104 The working arrangements document defines a '*missed site*' as any location which was planned to be treated within the base plan but was not treated within a 24-hour period, due to engineering access restrictions, fleet failure, resourcing issues, or any other factor preventing railhead treatment.

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[16] The Railways and Other Guided Transport Systems (Safety) Regulations 2006 (as amended) require infrastructure managers and transport undertakings to co-operate to keep the railway system safe by sharing information on risks, jointly meeting and reviewing risk assessments, and keeping their staff fully briefed. Rail Industry Standard RIS-8040-TOM 'Low Adhesion between the Wheel and the Rail - Managing the Risk' (issued December 2016, and updated in 2022) provides specific guidance on collaboration with respect to managing low adhesion.

105 If a planned treatment was to be delayed such that a site would not be treated in a 24-hour period, the Wessex route autumn working arrangements document stated that the network delivery manager should issue a 'missed site' form by 03:00 hrs on the day the treatment was planned to take place. Train operators were asked to acknowledge receipt of this form by email.

106 Railhead treatment can also be delivered across shorter stretches of track by TGAs. TGAs are attached to the rail at a fixed location and deposit adhesion modifier to the railhead before the passage of a train. The installation and maintenance of TGA equipment is set out in Network Rail standard NR/L3/TRK/3510/C01, 'Use of Traction Gel Applicators' (issue 1, September 2011). At route level, TGAs are managed by the SDS, who should arrange for the equipment to be positioned taking account of the risks of incidents caused by low adhesion. No TGA equipment had been installed on the Up or Down Salisbury Main lines at the time of the accident.

Monitoring and reporting of low adhesion

107 Network Rail's Wessex route's autumn working arrangements document also details how the WICC (figure 21) will respond to information about low adhesion received through reports from train drivers, feedback from MOMs identifying railhead contamination through their inspections, or notifications of wrong side track circuit failures (figure 22). Wrong side track circuit failures can occur if railhead contamination is such that it insulates trains' wheels from the rails to a degree that a train may be present but not detected. Such failures, which can be indicative of low adhesion risk, are monitored within the WICC by the intelligent infrastructure technician.

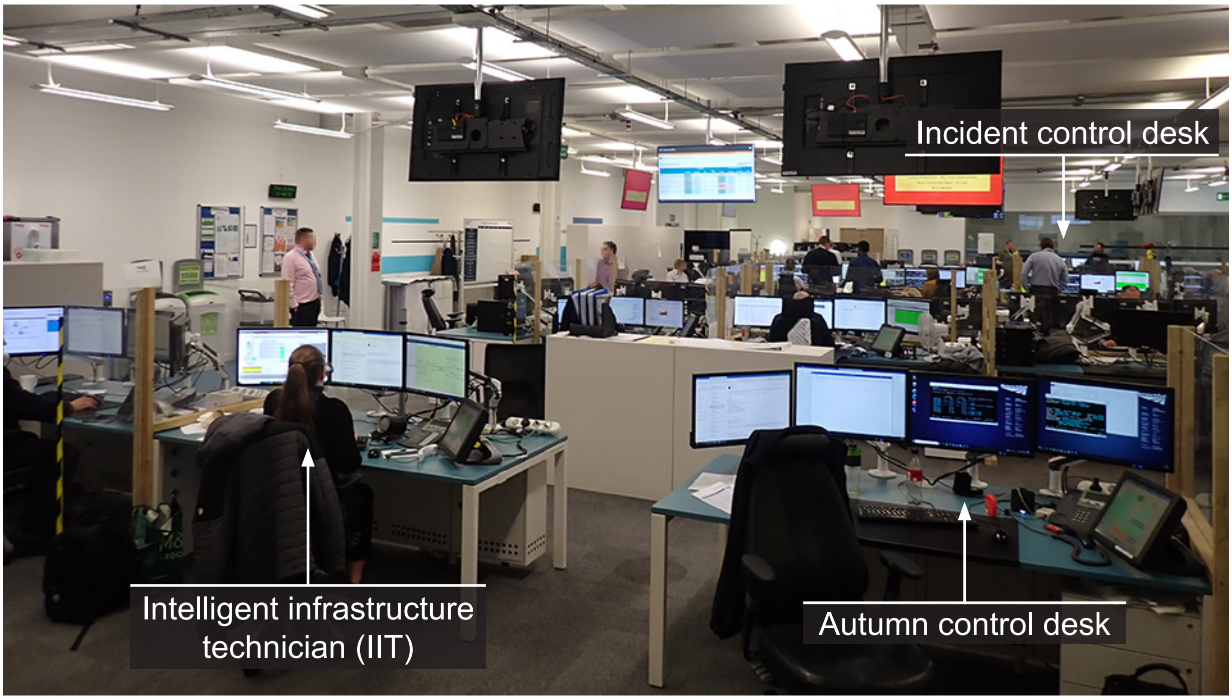

Figure 21: Wessex integrated control centre showing the location of various autumn management roles.

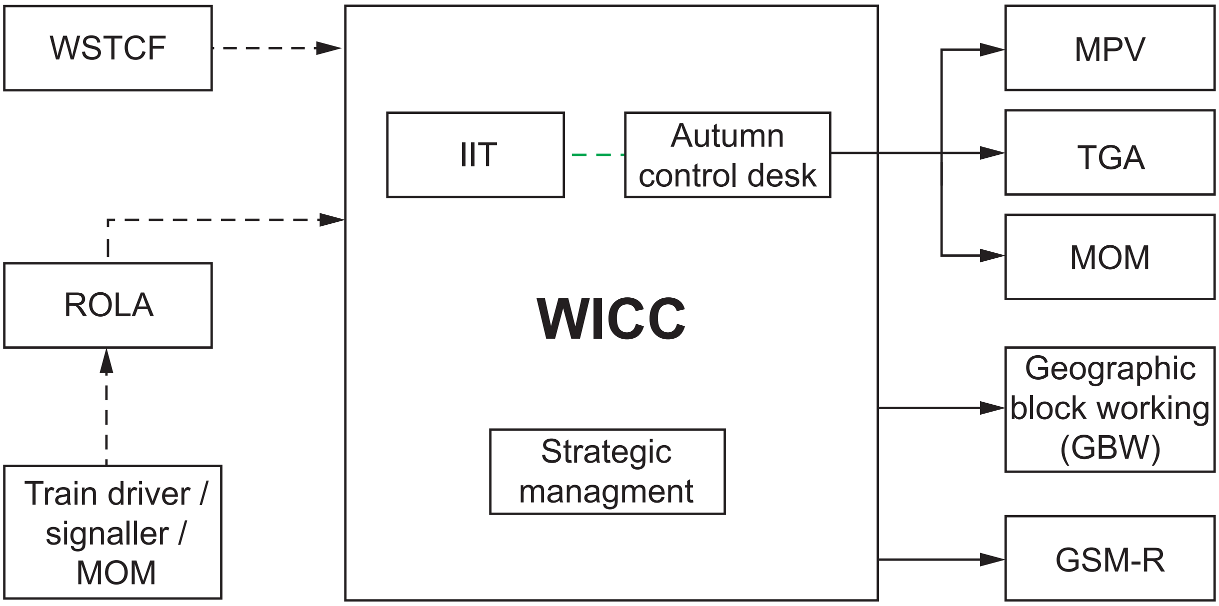

Figure 22: Sources of information coming into the WICC from reports of low adhesion and wrong side track circuit failures and mitigations that can be implemented to manage the low adhesion.

108 The need for drivers to report low adhesion conditions was set out in the railway Rule Book GERT8000 module TW1, ‘Preparation and movement of trains’ (issue 16, March 2021) and in SWR’s train driver briefings. The Rule Book classifies railhead adhesion as being *‘good’, ‘expected’* and *‘reportable’* with drivers only required to report the ‘*reportable*’ conditions to the signaller. This is defined as ‘*Railhead adhesion is worse than would be expected for the location and environmental conditions*.’ Signallers then pass that information on to operations control centres (such as the WICC) and also inform train drivers via a GSM-R message if the reported location is on the approach to a signal that can display a red aspect.

109 As well as section 28 of the Rule Book Module TW1, 'Preparation and movement of trains', train drivers must also follow their train operating company’s processes for reporting low adhesion, in this case the SWR Autumn brief for 2021. This again will not require them to report low adhesion at locations where it is expected. Consequently, a driver’s decision to report an incident is subjective and dependent on their previous experiences, knowledge of the route, published briefing notices (figure 23), and the environmental conditions on the day.

110 From 2020, the Wessex SDS implemented a scheme for an autumn control desk within the WICC. Autumn controllers make sure that all autumn-related information is collated and analysed in real time to identify any related emerging risk and keep all relevant parties informed. As part of this, they monitor and collate reports of low adhesion and wrong side track circuit failures from drivers and signallers. They also have a role to play in managing these risks by deploying available resources, such as MPVs, MOMs and maintenance resources, to mitigate the emerging risks of low adhesion.

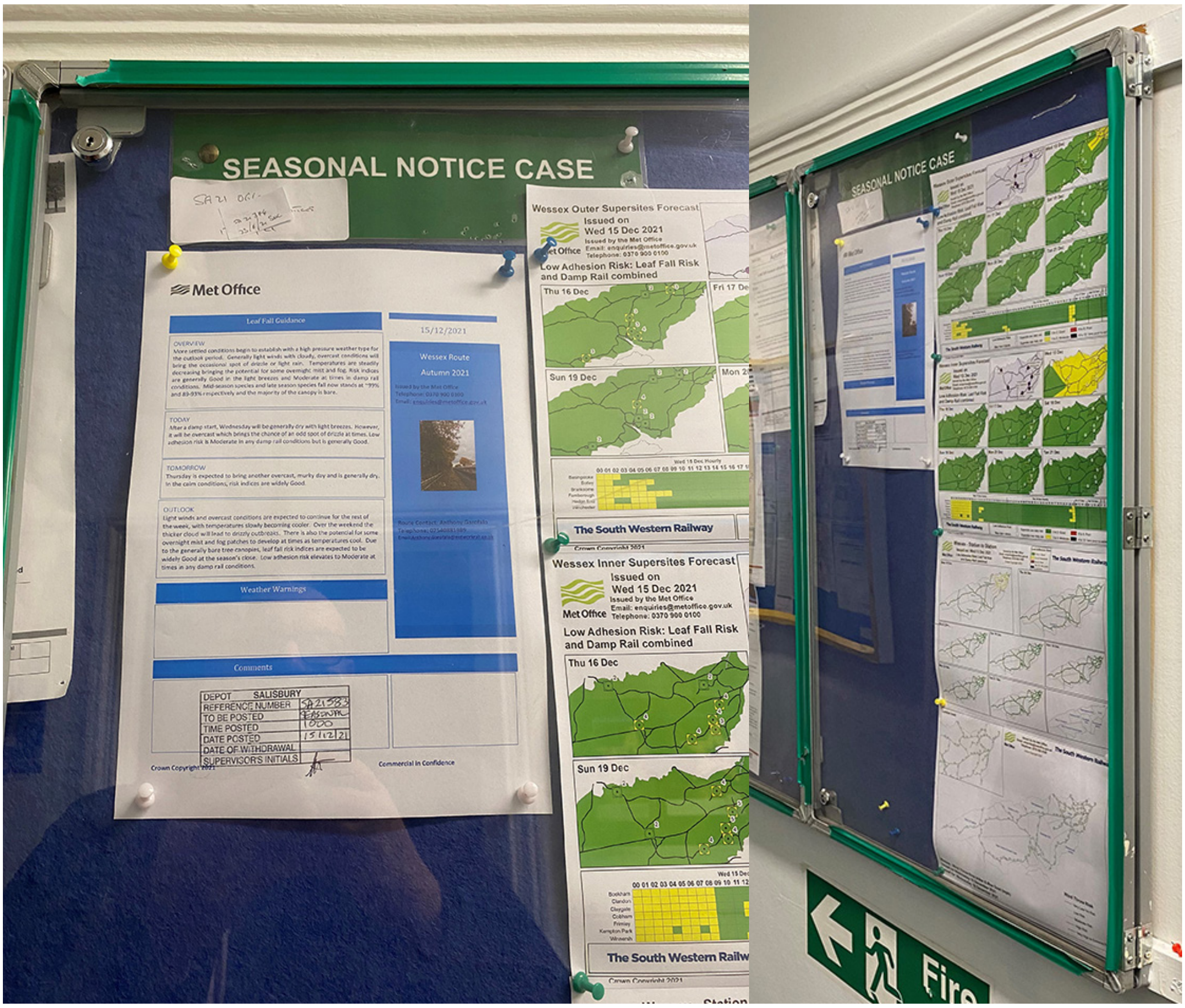

Figure 23: Weather and adhesion forecast notices placed alongside engineering notices in SWR's Salisbury depot.

Network Rail audit regime

111 Network Rail’s management assurance processes are set out in its company standard NR/L2/ASR/036, ‘Assurance Framework’ (issue 5, December 2017) and are intended to provide assurance at every level of the organisation that risk management systems are operating as intended. Network Rail has three levels of assurance varying from level 1 (line manager assurance) to level 3 (the level which provides the greatest independence).

112 A level 2 audit was carried out on Network Rail’s Wessex outer route MDU between January and March 2021. A level 2 functional and management system audit is conducted by an auditor independent from those with the responsibility of implementing the risk controls. The level 2 audit highlighted observations and non-compliances with the requirements of NR/L2/OTK/5201, ‘Lineside vegetation management manual’ (see paragraphs 226 and 261). The audit team concluded the overall rating was '*fair to good*' with a '*low to moderate*' probability of a risk event occurring.

113 A separate level 2 audit of Network Rail’s Western route in September 2019 identified issues with the competency and training requirements for the role of an SDS (see paragraph 257).

Identification of the immediate cause

114 **Train 1L53 passed signal SY31 at danger and could not stop before colliding with train 1F30.**

115 Signal SY31 at Salisbury Tunnel Junction was at red (danger) as it was protecting the paths of train 1F27 on the Up Dean line and train 1F30 on the Down Dean line (figure 3).

116 Train 1F27 was running around five minutes late, having been due to traverse Salisbury Tunnel Junction at 18:36 hrs. Train 1F30 was timetabled to pass through the junction at 18:23 hrs but was running around 20 minutes late, while train 1L53 was scheduled through the junction at 18:39 hrs and was running around four minutes late.

117 The signaller believed that train 1F30 would pass through Salisbury Tunnel Junction before train 1L53, and so they decided it would be more efficient to provide train 1F30 with a clear route while holding train 1L53 at signal SY31 to protect the movement.

118 Network Rail's policy and instructions for train regulation at Salisbury require signallers to give priority to passenger trains from the Dean lines unless those trains are running late by five or more minutes. When trains are running late, signallers use their experience to make decisions about the priority of services. The signaller's decisions and actions were consistent with these principles.

119 Train drivers are provided with the facility to make a railway emergency group call which will cause other drivers who receive the message to bring their trains to a stand immediately. Section 39.5 of the Rule Book[17] states:

> *'You must only use the emergency call facility when it is necessary to give immediate advice for trains to be stopped or cautioned, or to call the emergency services, in connection with an accident, obstruction or other exceptional incident.'*

120 The driver of train 1L53 stated that he was aware of this requirement but was hoping that the train's WSP and brakes would slow the train before the junction, and he was concerned that a train could be bought to a stop across the junction. By the time he saw signal SY31 was still at red he was becoming distressed. Soon after, he saw train 1F30 approaching the junction and took action to leave the cab (paragraph 68).

121 RAIB believes that, given the instruction, it is reasonable to assume that a driver is unlikely to decide to make a railway emergency group call until they have seen that the protecting signal has remained at red and their train is continuing to travel uncontrollably. Analysis undertaken by RAIB indicates that, in such circumstances, the driver of train 1F30 is unlikely to have received sufficient warning to bring that train to a stop before a collision.

[17] The Rule Book extract is taken from issue 16 of GERT8000-TW1 which came into force in June 2021.

Identification of causal factors

122 Train 1L53 passed signal SY31 and ran onto the junction due to a combination of the following causal factors.

a. Wheel/rail adhesion was very low in the area where the driver of train 1L53 applied the train's brakes (paragraph 123).

b. The driver did not apply train 1L53's brakes sufficiently early on approach to protecting signal SY31 to avoid running onto the junction, given the prevailing levels of wheel/rail adhesion (paragraph 172).

c. The braking systems of train 1L53 were unable to mitigate the effects of the prevailing wheel/rail adhesion (paragraph 203).

Each of these factors is now considered in turn.

Very low wheel/rail adhesion

123 **Wheel/rail adhesion was very low in the area where the driver of train 1L53 applied the train's brakes.**

124 Trains rely on friction between the wheel and rail to slow down and stop; this can be affected by contaminants such as crushed leaves which, when combined with moisture, reduce the level of wheel/rail adhesion (paragraph 81 and table 1). While WSP systems (paragraph 40) can mitigate a reduction in wheel/rail adhesion to a degree by maximising the use of available friction, ultimately, if levels of friction are sufficiently low, a train will decelerate much more slowly than normal, particularly on a descending gradient.

125 As the driver was braking, the very low level of wheel/rail adhesion in the area where the driver braked meant that the train's braking performance was lower than normal (paragraph 62, figures 24, 36 and 40).

126 Evidence for low wheel/rail adhesion encountered by train 1L53 is provided by data from the train and the driver's account. OTDR data from train 1L53 shows that the train's WSP system was active throughout the brake application on approach to signal SY31, as would occur when a train encounters low wheel/rail adhesion conditions.

127 Following the accident, RAIB tested the train's WSP system (see paragraph 203) and used data from the train to derive the values of adhesion encountered by train 1L53 from the point at which the brakes were applied on approach to signal SY31 on the night of 31 October 2021. This analysis determined that the train was likely to have encountered average levels of adhesion between 0.04 and 0.05. This equates to very low wheel/rail adhesion conditions (as defined in table 1).[18]

128 The level of wheel/rail adhesion was very low due to contamination on the railhead (see paragraph 129) and Network Rail's Wessex route not effectively mitigating the railhead contamination (see paragraph 156).

[18] Recovery, tribology testing and analysis of railhead contamination samples was completed on site by RAIB and University of Sheffield. Analysis of the train's systems and WSP was completed using the WSPER testing rig (see paragraph 216). The combination of the results from the various testing and analysis indicated that the level of adhesion on approach to signal SY31 is likely to have varied between low and very low.

Railhead contamination

129 **The railhead was contaminated with fallen leaf debris, much of it as a result of the weather conditions since the last railhead treatment run, coupled with an increased density of vegetation, and wet conditions from the band of drizzle that had recently passed over.**

130 When RAIB deployed to the site of the accident on the night of 31 October 2021, its inspectors undertook an initial visual examination of the Down Main line on the approach to the accident site. The railhead generally showed signs of medium contamination (level 2), but with some evidence of heavy contamination (level 3), where the driver started braking and on the immediate approach to Fisherton Tunnel. Comparison with the guidance given in Wessex route's autumn working arrangements document for assessing contamination indicated that the levels of contamination found on the approach to the braking zone used by train 1L53 and on the approach to Fisherton Tunnel would be likely to have resulted in low to very low adhesion (paragraph 84 and figure 24). All the contamination found was comparable with that expected from successive train wheels crushing leaf material and other contaminants onto the railhead, building up the thickness of contamination in layers (paragraph 82). Testing undertaken in 2006 suggested that a significant percentage of any railhead contamination would be removed by water jetting (paragraph 83 and see paragraph 245). As such, much of the contamination would have been a result of the weather conditions since the last railhead treatment MPV run (see paragraph 133) coupled with a high density of vegetation and topography on the various sections of the Down Main line (see paragraph 136).

131 RAIB commissioned the University of Sheffield to conduct a detailed tribology (friction) survey at 12 sample locations over 3.3 km on approach to the accident site (figures 24, 25 and 26). This survey took place on 3 November 2021, while the line remained closed and undisturbed. Measurements and samples were taken under wet and dry conditions. In dry conditions, values of the coefficient of friction were measured as being between 0.09 and 0.35, while for wet conditions the values were measured as being between 0.02 and 0.20. The University of Sheffield also noted that '*most wet values for the contaminated rail head samples that were analysed were below those required for effective braking*'.

132 A sample taken at 81 miles 40 chains (where the train had full service braking applied) showed an increase in the level of silica (a component of sand). This may have been due to the activation of sanding systems on trains passing over the line, including the one on train 1L53. Subsequent sample locations on approach to the accident site had an appearance consistent with train wheels having slid over them.

Weather conditions on the day of the accident

133 In addition to the leaf fall density provided by MetDesk (figure 18), Met Office data going back to 2016 showed that, around the time the accident occurred, the trees in the area were approximately two weeks behind the normal leaf fall schedule, having around 65 to 70% of their leaves remaining. The wind and rain on the day of the accident (paragraph 43) almost certainly resulted in increased leaf fall and this is likely to have contributed to the high levels of contamination observed on the section of line approaching Salisbury and the approach to the junction.

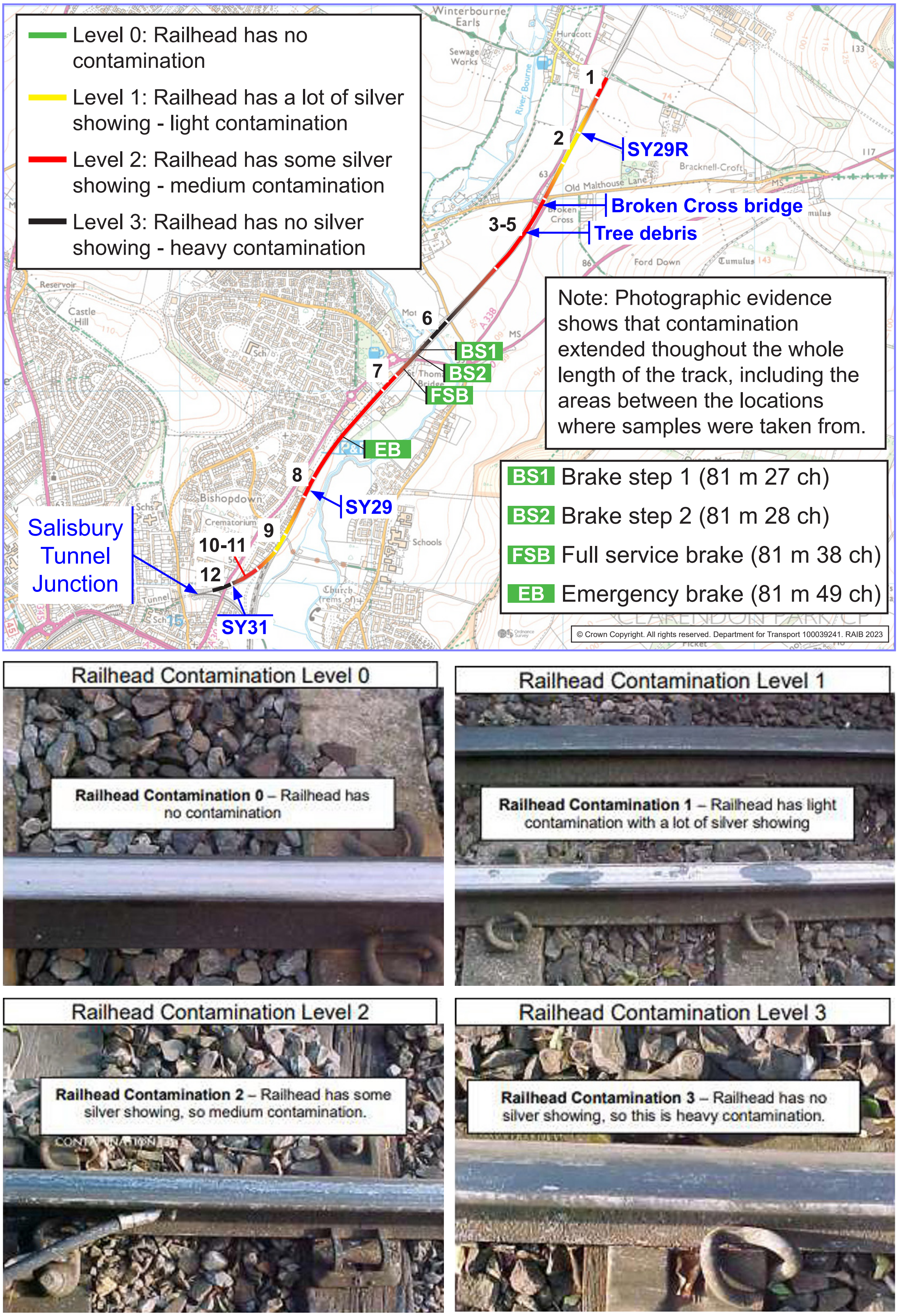

Figure 24: Post-accident sample locations and (below) Network Rail classification of contamination levels (NR/L3/OPS/045/4.07).

Figure 25: Location (left) and railhead condition (right) at 80 miles 40 chains.

Figure 26: Location (left) and railhead condition (right) at 82 miles 27 chains beyond signal SY31 and approaching Salisbury Tunnel Junction.

134 Network Rail records for 31 October 2021 showed that fifteen trees fell on railway lines within the Wessex route (paragraph 48), causing major disruption. Although trees do not naturally shed their leaves when they have been felled, the resulting detritus will spread and may result in further localised contamination of the railhead.

135 Wet wheel/rail adhesion levels on a contaminated railhead are significantly lower than dry adhesion levels. The wheel/rail adhesion conditions encountered by train 1L53 would have been adversely affected by a band of drizzle which passed over the Salisbury area between 18:35 and 18:40 hrs (figure 6), around five minutes before the train approached Salisbury Tunnel Junction. This also meant that train 1L53 probably saw significantly reduced wheel/rail adhesion compared to the two previous trains that had been required to stop at signal SY31 (see paragraph 178).

Vegetation management

136 Vegetation management is undertaken by the off track section within Network Rail's maintenance organisation[19] in accordance with the requirements of Network Rail standard NR/L2/OTK/5201, 'Lineside vegetation management manual' (issue 5, December 2020) (figure 27). This standard covers all elements of vegetation inspection, assessment and management of the risks associated with trees falling on or near the railway, ensuring necessary sightlines to signals, autumn leaf fall risk and preserving biodiversity. When issues are identified during vegetation inspections, off track staff raise a work order using a work arising identification form (WAIF) which is entered into the Network Rail Ellipse maintenance system.[20] This form specifies the work to be undertaken and the recommended timescales for completion, from immediate action up to 12 months, depending on the associated risk. Inspections are to be carried out during periods of vegetation growth in summer. Therefore, any actions that may have an impact on low adhesion risk that year would need to be completed within three months of the inspection so that the risk is mitigated before the autumn season.

137 Network Rail standard NR/L2/OTK/5201 Module 03, 'Route Vegetation Management Plans' allows the section manager for off track to reprioritise lineside vegetation work. NR/L3/MTC/MG0176, 'Ellipse Management Handbook: Prioritisations, Reprioritisations and Cancellations' allows for deferment of work on Ellipse up to five times before authorisation is required from the SAE. Depending on the risk from the vegetation at the time of the reprioritisation, the work can be delayed by up to 12 months on each occasion.

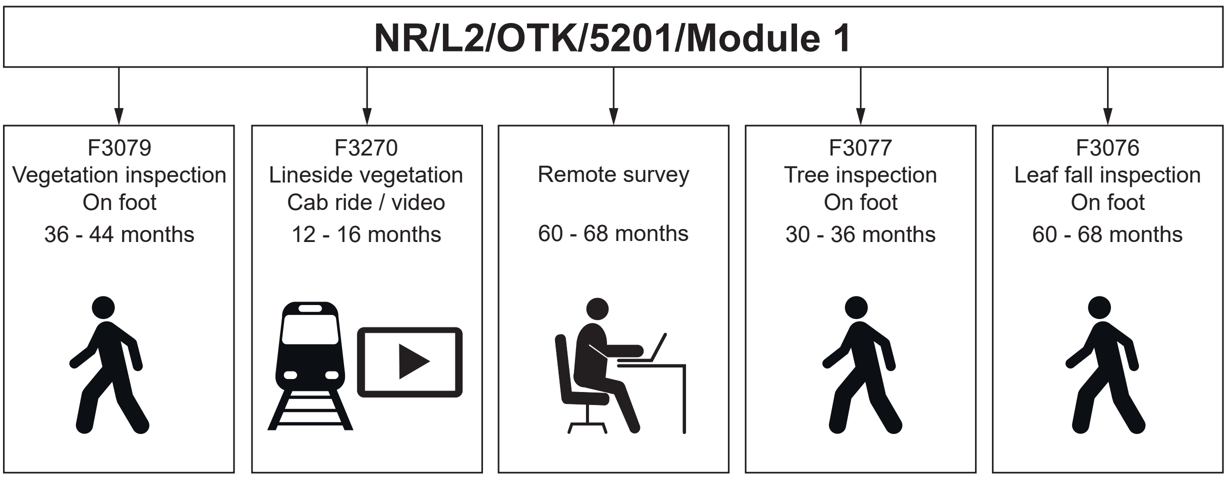

Figure 27: The various assessment regimes and periodicities for tree, vegetation and leaf fall within Network Rail standard NR/L2OTK/5201/module 1.

[19] Wessex Route Area Services team also managed contractors to undertake off track maintenance, including vegetation clearance on the Wessex route.

[20] Ellipse is an integrated asset and work management system which helps planning of work to be performed on the railway infrastructure (see also figure 41).

138 NR/L2/OTK/5201 specifies a suite of vegetation inspections, one of which is an on-foot leaf fall inspection to be undertaken every 60 months. These are to be undertaken by off track inspection staff within the MDU or can be contracted out. During these inspections, the inspector is required to complete form NR/L2/OTK/5201/F3076, which scores each one-eighth mile (approximately 200 metres) using criteria including tree density, tree size, distance from the track, the presence of other vegetation and topography. The output from a leaf fall assessment is a numerical score from 0 to 32. This figure is also entered into Ellipse.

139 Operation standard NR/L2/OPS/095, 'High Risk Sites for Wrong Side Track Circuit Failures in Leaf Areas and for Low Rail Adhesion' (issue 6, June 2019) describes Network Rail's business process for identifying and managing the risks from railhead contamination causing low adhesion and WSTCF. The standard requires the SDS to convert the leaf fall inspection score from NR/L2/OTK/5021/F3076 into a risk level and to reassess each location on an annual basis. NR/L2/OPS/095 classifies a score above 26 as high risk (risk category 5). The standard requires that high risk sites are added to Network Rail's record of HRLA sites and that the details are shared with the operational standards department of relevant train operators. The standard also requires the SDS to lead and co-ordinate plans to remove high risk sites (removal plans), although individual plans may be owned by others, for instance the SAE or track maintenance engineer (TME). The SDS is also required to consider appropriate mitigations in the interim to reduce the probability of a low adhesion incident, such as a SPAD. RAIB observes that NR/L2/OTK/5201 and form NR/L2/OTK/5021/F3076 both also classify a score between 21 and 26 as being *'high risk during the peak leaf fall period and wet conditions'*, however NR/L3/OPS/095 does not require any action to be taken for sites with these scores (paragraph 88).

140 Standard NR/L2/OPS/095 also requires that all HRLA and high risk of WSTCF sites are subject to an adhesion risk assessment process using form NR/L2/OPS/095/F01. This takes into account the associated probability and impact of a low adhesion event and classifies the risk at locations on a scale of between 2 (low risk) and 10 (high risk).

141 In 2018 and 2019 Network Rail revised standard NR/L2/OTK/5201 with the aim of aligning its operational and vegetation management standards and to include more detail on undertaking lineside inspections. It also rolled out an associated training programme to facilitate more inspections by MDU staff, in particular the leaf fall inspections. The training programme was provided to MDU managers with an expectation that they would cascade the training to off track inspectors undertaking lineside inspections. Witness evidence is that training was not provided to arboriculture contractors used by Network Rail's Wessex route, although senior managers in Network Rail expressed an opinion that contractors would be included in the cascading of such training. However, RAIB observes that NR/L2/OTK/5201 states that *'contractors are responsible for undertaking their own technical and awareness briefings in accordance with their own processes and procedures'*.

142 Network Rail's Wessex route was unable to provide any data from leaf fall inspections before 31 October 2018. However, witness evidence suggests that from 2016 a section of track between Overton (55 miles 42 chains) and Whitchurch (59 miles 8 chains), just over 20 miles from the accident site, had been classified as a 'supersite', that is, one suffering from excessive leaf fall resulting in railhead contamination causing frequent WSTCF. Figure 28 shows the effects of vegetation work undertaken during 2019/20. There is no evidence to suggest that the track in the vicinity of the accident had been classified as a 'supersite'. In the absence of any historical documentation, RAIB was unable to confirm the technical basis for categorising a site as a low adhesion 'supersite', but it is possible that this was what later became known as an HRLA site.

Figure 28: The main lines between Overton and Whitchurch looking towards Salisbury showing the condition of the vegetation before (taken in summer) and after (taken in winter) vegetation work was completed in 2019/20.

143 Leaf fall risk inspections were completed between 31 October and 2 November 2018 from 50 miles to 83 miles on the Salisbury line. Although Network Rail could not provide copies of the completed leaf fall inspection forms, RAIB was able to view the leaf fall inspection scores that had been supplied to the then SDS and SAE. These scores showed that sites on the main lines between 80 miles 30 chains and 80 miles 40 chains, and 81 miles 10 chains and 81 miles 20 chains had been categorised as level 5 sites, with scores of 27 and 28, respectively. Sites between 80 miles 50 chains and 80 miles 70 chains, and 81 miles 20 chains and 81 miles 30 chains were categorised as level 4 sites. Rather than having two individual one-eighth mile sections close together, the entire length of track covering both level 5 sites and the track in between, almost a mile in total, was designated as a single HRLA site (figure 30). This single site encompassed the Down Main line starting at Broken Cross bridge and terminating around 940 metres on approach to signal SY29. RAIB found that these scores were not entered into Ellipse. In addition, the site was not added to the table of HRLA sites, and no vegetation plan or mitigation was actioned for it.

144 In 2019 a further leaf fall inspection was undertaken, for which again only the scores were available. These indicated that the main lines between 80 miles 30 chains and 81 miles 20 chains had again been categorised as a level 5 site. RAIB found again that these scores were not added to Ellipse, nor was the site added to the table of HRLA sites, although it was subsequently added in 2020. Despite the site being added to the table, no vegetation plan or mitigation was actioned for it by Network Rail and the site was not included in SWR's 2020 autumn briefing.

145 RAIB has been unable to determine why no removal plan or mitigations were implemented for this HRLA site between 2018 and 2020. The SDS in post at the time of the accident reported that they were unaware that no action had been taken. However, RAIB found that the collaboration between the SDS, SAE, and MDU TME and SM for off track staff had been ineffective and the SDS had not checked on the presence or status of any removal plans because it had "always been like that" (see paragraphs 229, 231 and 253).

146 In June 2021, arboriculture specialist contractors undertook a further leaf fall inspection of the Down Main line. The results from this assessment showed the presence of several level 4 sites between 80 miles 30 chains and 82 miles 30 chains but no level 5 sites (figure 29). The risk scores resulting from this inspection for the sites that had previously been identified on the Down Main line in 2018 and 2019 as level 4 or level 5 were scored at lower levels. Of particular note was the section around 80 miles 30 chains. This was reassessed as a level 1 site having previously been scored as a level 5 site. This scoring meant that none of the line was categorised as being an HRLA site and, as such, no actions to reduce the trees or vegetation were required. However, RAIB found that this section was not removed from the table of HRLA sites, likely because the SDS risk assessment process (paragraph 139) is undertaken on an annual basis and requires consideration of other operational experience as well as the leaf fall risk assessment.

147 No action to manage the vegetation had been taken between 2018 and 2021 and video footage shows that vegetation continued to grow on the main lines approaching Salisbury Tunnel Junction between 2019 and 2021. A comparison between the 2021 scores and those from earlier inspections therefore brings into question the robustness of the process. It is also unclear whether classification of sites with an assessment score of between 21 and 26 as *'high risk during peak leaf fall period and wet conditions'* in NR/L2/OTK/5201/F3076 may have affected the contractors' scoring. As explained in paragraph 139, operational standard NR/L2/OPS/095 did not require any action to be taken for such sites, but the contractors were unlikely to have been aware of this. Figure 32 shows the change in the management of vegetation at Salisbury Tunnel Junction over the previous decades.

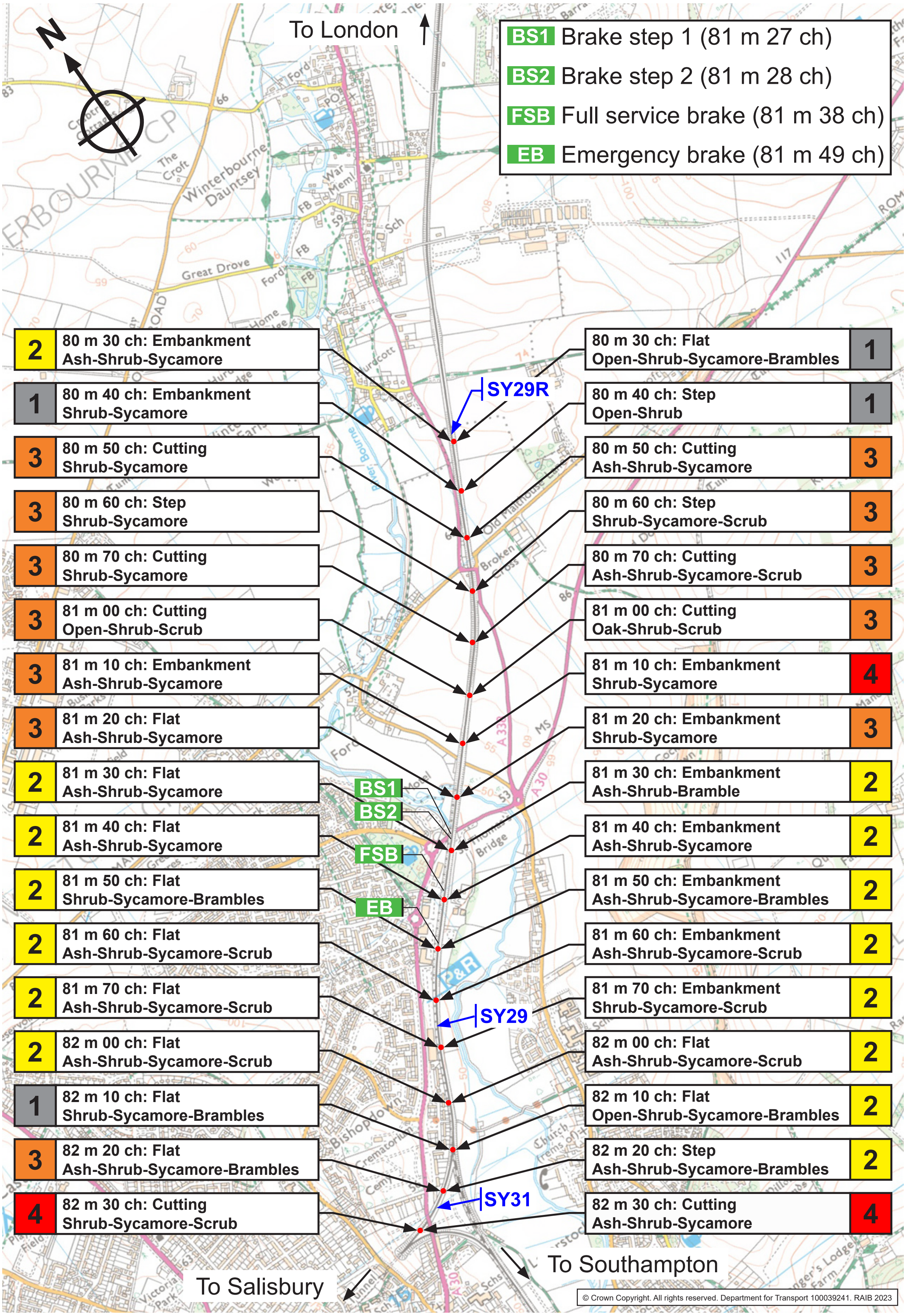

Figure 29: Network Rail (Wessex) data in diagrammatic format showing mileage, topography, tree species and leaf fall risk assessment data scores (June 2021).

Location	ELR	Line	Start Mileage	End Mileage
Hersham to Weybridge	BML1	DS and DF	15m 37ch	19m 54ch
Farnborough to Fleet	BML1	All	32m 45ch	37m 0ch
Basingstoke to Worting Junction	BML1	US and UF	47m 13ch	50m 21ch
Wallers Ash to Shawford	BML1	All	61m 50ch	69m 50ch
Brockenhurst to Hinton Admiral	BML2	Down	92m 66ch	101m 10ch
Bournemouth to Parkstone	BML2	All	107m 60ch	112m 46ch
Wool to Moreton	BML2	All	124m 73ch	131m 0ch
Milford to Witley	WPH1	All	35m 40ch	39m 0ch
Wilton Junction	BAE2	All	84m 24ch	88m 20ch
Foxhills Tunnel to Aldershot Junction	PAA1	Down	31m 0ch	33m 40ch
Bramley	BKE	All	45m 60ch	47m 20ch
Basingstoke	BKE	All	50m 15ch	51m 20ch
Chandlers Ford	ECR	Single Line	73m 70ch	80m 0ch
Eastleigh Junction South to Botley	ETF	All	74m 4ch	78m 72ch
Hamble to Fareham station	SDP1	All	6m 22ch	14m 14ch
Coustons Bottom LC to Wilton Junction	SAL	Down Warm	130m 16 ch	132m 33ch
Ashstead to Mickleham Tunnel	BTH3	All	16m 40ch	19m 55ch
Maldon Manor to Chessington South	MPC	All	11m 5ch	13m 73ch
Fulwell to Shepperton	NMS2	All	12m 75ch	18m 73ch
Claygate to Clandon	NGL	All	15m 0ch	26m 21ch
Effingham Junciton to Leatherhead	LEJ	All	22m 15ch	18m 44ch
Viginia Water to Englemere UWC	RDG1	All	23m 15ch	30m 36ch
Wokingham to Reading Spur Junction	RDG2	All	62m 8ch	67m 76ch
Weybridge to Chertsey	VWW	All	19m 12ch	24m 73ch
Ascot to Frimley Junciton	AAV	All	29m 0ch	38m 46ch
North Camp to Farnborough North	GTW2	Down	51m 18ch	53m 16ch
Blackwater to Wokingham	GTW2	All	55m 58ch	62m 8ch
Gomchall to Shalford	RSJ	All	35m 21ch	41m 2ch
Worting Jn-Whitchurch	BAE1	Up and dn	*53m 20ch*	*60m 10ch*
Hook	BML1	Up Slow and Fast	42m 40ych	44m 70ch
Liphook	WPH1	Up and dn	46m 70ch	47m 0ch
Bentley to Alton	PAA2	Single line	44m 40ch	49m 10ch
Worplesdon	WPH1	Up and Dn	26m 40ch	27m 0ch
Gateley- Laverstock Jn	BAE1	Up and dn	80m 30ch	81m 20ch
Yeovil (Grove Famn Xing)	BAE2	Single line	127m 20ch	127m 60ch
Finchdean	WPH1	Dn	61m 20ch	61m 70ch

Figure 30: Table of high risk low adhesion sites showing details of the location, engineers line reference (ELR), line, start and end details (miles and chains). Misspelling of Grateley and other names are from the original document.

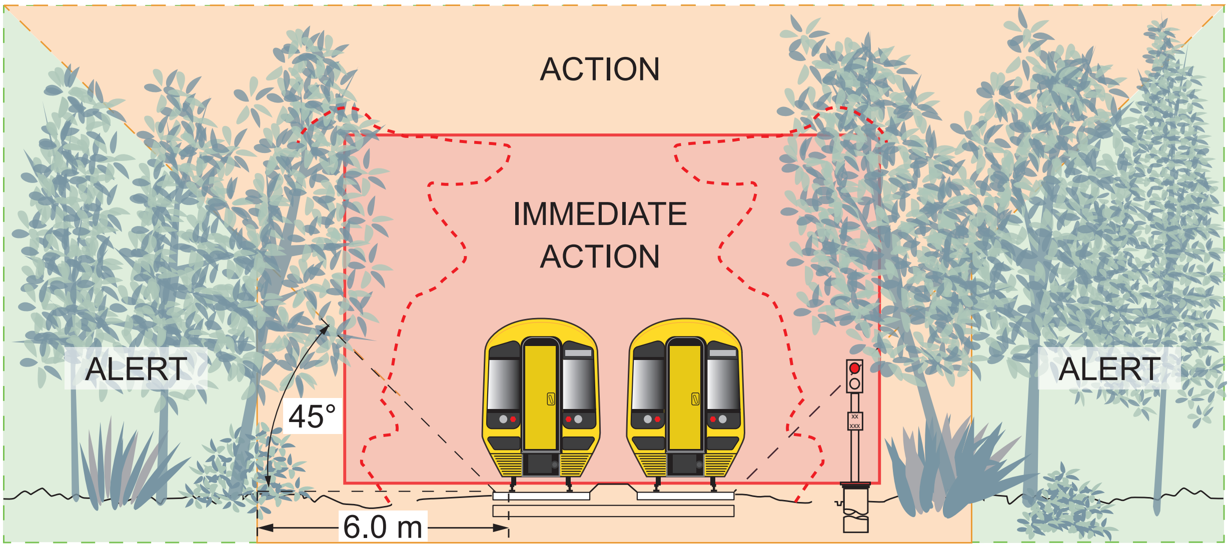

Figure 31: RAIB diagram showing the action zones from Network Rail standard NR/L2/OTK/5201, train profiles similar to class 159 trains, and tree growth as found on certain sections of the main lines between signals SY29R and SY31 (red dotted line).

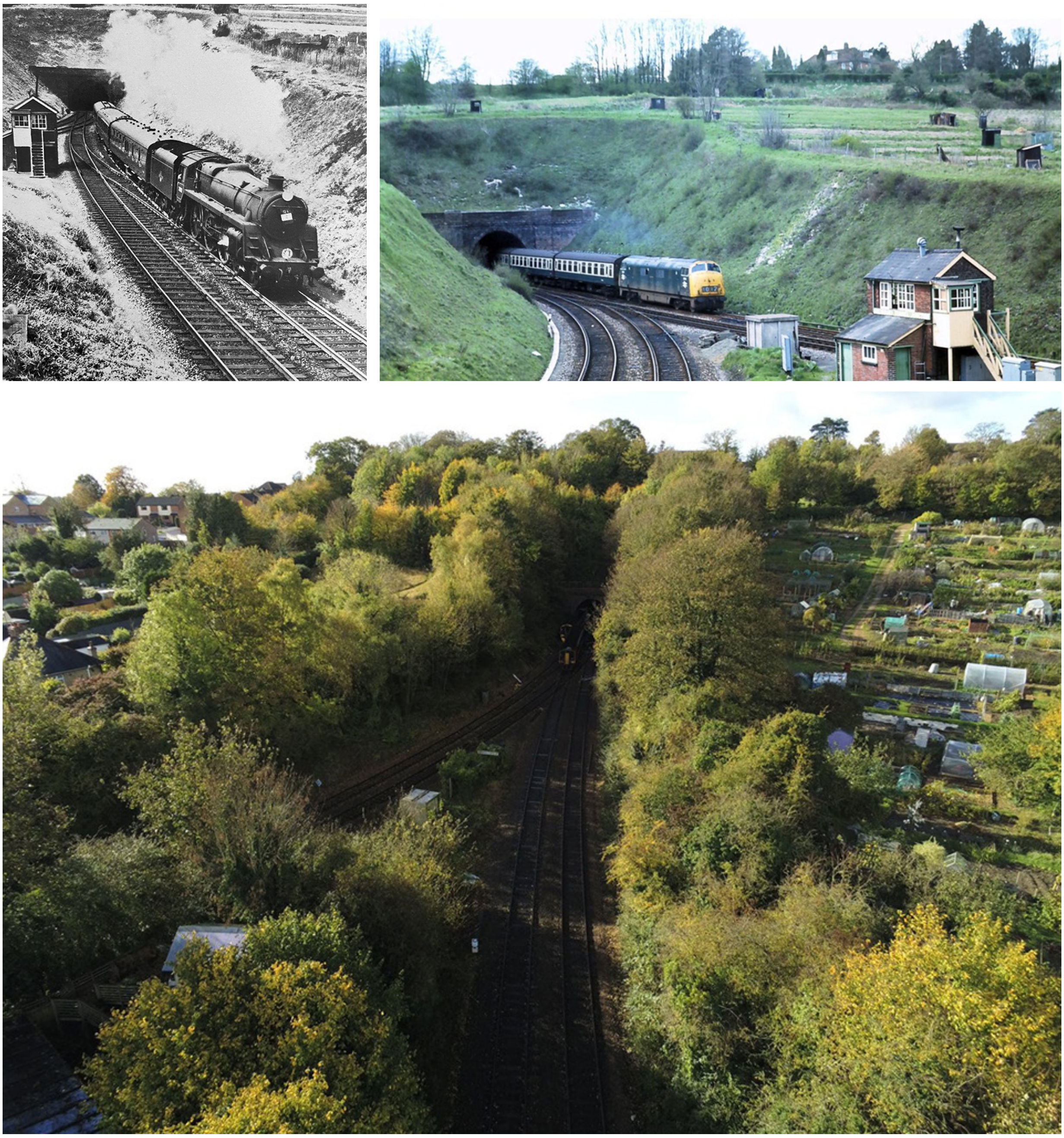

Figure 32: The Up and Down Dean and Main lines looking towards Fisherton Tunnel in 1963 (top left, courtesy of Crecy publishing), in the 1970s (top right, courtesy of Crecy publishing), and on 1 November 2021 (main image).

148 Furthermore, an examination of the section of line from signal SY29R to beyond signal SY31 after the accident (paragraph 130) showed there were areas of medium to heavy railhead contamination which would have resulted in low levels of wheel/rail adhesion, even on sections that had low scores in the 2021 risk assessment. The amount and condition of the vegetation and trees were also seen to be non-compliant with the wider requirements of NR/L2/OTK/5201 (figure 31).

149 While the risks of trees falling or encroaching onto the railway are separate from those associated with leaf fall, any vegetation management activity undertaken in response to these risks will likely have associated benefits for preventing leaf fall and reducing the likelihood of low adhesion.

150 Witness and documentary evidence shows that an on-foot inspection of the vegetation was also undertaken by a member of Wessex outer MDU's off track staff on 14 June 2019. The inspection recommended trees and vegetation be cut back as they had encroached into the 'action zones' as shown within Network Rail standard NR/L2/OTK/5201 (figure 31). Records showed that the data was entered into the Ellipse system in June 2019 with a timescale for action within 12 months, although on the 12-monthly review this was deferred by a further 12 months to June 2021.

151 The action timescales and their subsequent deferment may have been affected by the lack of contextual information available to Wessex outer MDU off track staff. Although MDU off track staff were provided with the Wessex autumn working arrangements document showing the locations designated as HRLA sites and where WSTCF had occurred as a result of low adhesion, this information was not used by them, nor were they given any details of recommendations from previous inspections. As a consequence of this, work could be reprogrammed without taking account of the wider implications of leaf fall increasing the risk of low adhesion.

152 The last vegetation inspection undertaken by the MDU before the accident was carried out remotely between 13 and 14 June 2021 by the section manager reviewing footage that had been taken the previous week from high-definition trainborne cameras (figure 33).[21] No WAIFs were raised from this inspection since the section manager was aware that existing work orders were already in Ellipse from the previous inspection in 2019. The tree and vegetation work to reduce the risk was further deferred to April 2022 (paragraph 150).

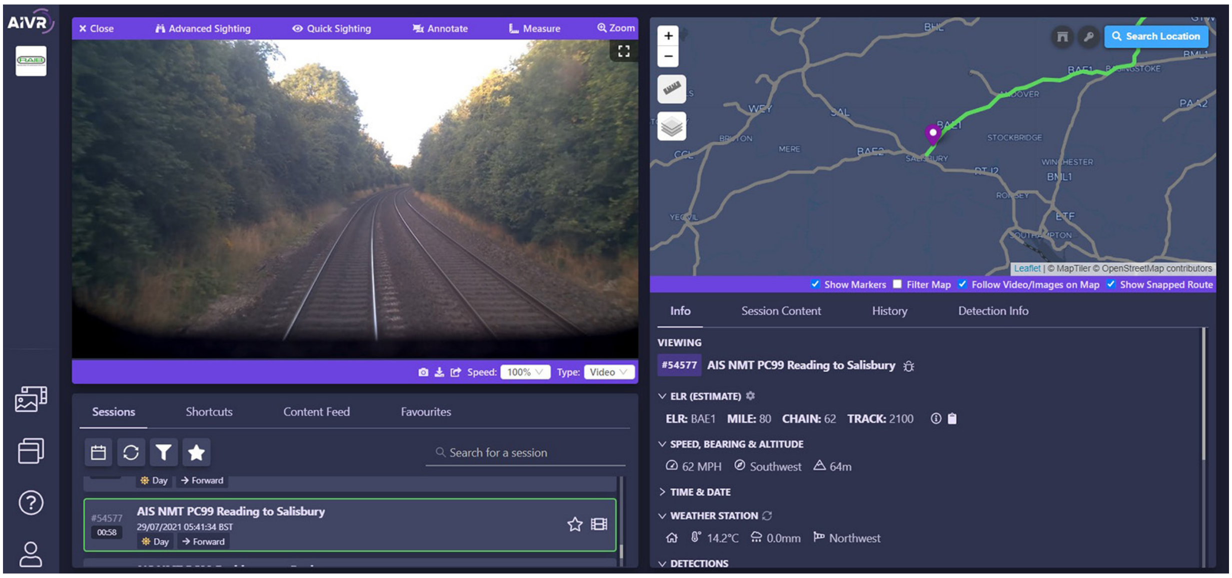

Figure 33: Automated Intelligent Video Review software for cab/remote assessments of vegetation (image courtesy of Network Rail and One Big Circle).

21 Remote monitoring was introduced as a result of new lineside inspection safety restrictions and cab ride restrictions due to the COVID-19 pandemic.

153 The off track section manager and the TME stated that much of the vegetation work in their area had been deferred due to other higher priority work, including drainage assessments in response to the accident at Carmont on 12 August 2020 (see paragraph 326), as well as resource issues in the off track section (see paragraph 225).

154 This lack of action was possibly also because the TME and off track section manager were not aware of the risk from leaf fall, as the MDU off track staff had not entered the leaf fall scores into Ellipse, and no vegetation management plan for leaf fall risk had been developed.

155 However, witness evidence also suggests that, even if the leaf fall scores had been entered into the Ellipse system, it is unlikely that this would have resulted in actions to address the risk through vegetation management. This was because off track staff in the MDU neither had the competence to interpret the leaf fall data, nor did they accept that the leaf fall inspection process and managing the risk of leaf fall reducing railhead adhesion was within their remit, despite it being defined as such in Module 1 of NR/L2/OTK/5201. MDU off track staff believed instead that this was a track maintenance issue (see paragraph 259).

Management of railhead contamination

156 **Network Rail's Wessex route had not effectively mitigated the railhead contamination.**

157 Besides the management of trees and vegetation, infrastructure managers can take proactive and reactive steps to mitigate the risks arising from railhead contamination. However, Network Rail's Wessex route did not take effective action to address these risks on the approach to Salisbury Tunnel Junction over the weekend of 30/31 October 2021.

Proactive mitigation measures

158 As part of Network Rail's planning for autumn, an SDS gathers information to understand the status of lineside vegetation and whether the level of risk requires proactive mitigation. At HRLA sites, this mitigation can include signage to warn drivers of low adhesion, and TGA equipment, although neither of these were actually installed on the Down Main line on the approach to Salisbury. Scheduling runs of the railhead treatment MPV fleet using both water and adhesion modifier can also be implemented. An SDS can also arrange for sections of track outside of HRLA sites to be treated as needed.

159 The site where the driver braked train 1L53 on the Down Main line on the approach to Salisbury Tunnel Junction did not include any HRLA sites. However, the area was nevertheless scheduled for treatment with water using the MPV throughout the leaf fall season.

160 In accordance with the 2021 autumn working arrangements, a railhead treatment MPV was due to run over the Up and Down Main lines once on the morning of Saturday 30 October 2021 and again on the afternoon of Sunday 31 October 2021. The MPV ran as scheduled over the Down Main line and Salisbury Tunnel Junction at around 11:06 hrs on 30 October. However, although the MPV was due to pass over this section of track again at 17:03 hrs on 31 October, around 1 hour and 40 minutes before the accident, this run was postponed until 23:00 hrs on 31 October. This postponement was programmed on 25 October and was due to planned engineering work, which would block the exit from the MPV depot.

161 Witness and documentary evidence shows that Network Rail's autumn mitigation measures, such as the railhead treatment programme, were given a lower priority than timetabled passenger services and engineering work. This meant that MPV treatment runs were frequently delayed or cancelled at weekends when much scheduled engineering work takes place.

162 Because the delay to the MPV run on 31 October was planned in advance, and the MPV would still run within the planned calendar day, Network Rail did not consider the postponement to be a missed site. RAIB observes that the autumn working arrangements document includes an aspiration for routes to be treated once per 24 hours (paragraph 102) and therefore this decision was inconsistent with that aspiration. However, the fact that it was not considered as a missed site meant that no additional mitigations or control measures were considered or adopted, even though Network Rail's Wessex route control staff were aware that poor weather with a high risk of leaf fall was predicted (see paragraph 250).

163 The MPV ran in accordance with the autumn working arrangements plan during the previous week. RAIB found no faults with the water jetting equipment on the MPV used on 30 October, and its OTDR and GPS records confirm that the Down Main line, including approach to signal SY31, was treated, although water jetting was suspended on the immediate approach to Salisbury Tunnel Junction. RAIB cannot be certain of the effectiveness of the treatment on 30 October, however, the performance of train 1L53 and inspections carried out after the accident (paragraphs 130 and 131) suggest that any significant benefit of the treatment had been nullified by the time of the accident.

164 Although the MPV normally treats the railhead with water jetting, treatment can be enhanced with the addition of an adhesion modifier (paragraph 100). However, the SDS did not consider the area in which the driver of train 1L53 braked (81 miles 27 chains to 82 miles 35 chains) to present a risk that required the use of adhesion modifier. The SDS stated that the previous SDS had had reservations about the effectiveness and value for money of using an adhesion modifier and the incumbent SDS did not believe that decision needed to be reviewed. Furthermore, even if the SDS had seen the value of using an adhesion modifier, they are unlikely to have requested its use outside of an HRLA site. This meant that the railhead was only treated with water jetting. Although it is possible that the use of an adhesion modifier on 30 October would have improved the wheel/rail friction, any benefit would probably have been reduced by the passage of trains and additional leaf fall by the time of the accident.

Reactive mitigation measures

165 On Friday 29 October 2021 the SDS chaired a tri-weekly teleconference to discuss the autumn working arrangements for the next few days, in accordance with the Wessex autumn working arrangements document. The meeting involved several stakeholders, including MetDesk and the Met Office, and provided an opportunity to consider any necessary operational mitigations that might be required in response to forecast weather.

166 At the meeting, the forecasters confirmed that adverse weather would occur over the weekend of 30/31 October, with inland wind gusts of 40 to 45 mph (64 to 72 km/h). The forecasts predicted that it was likely that the rail network in Hampshire and Wiltshire, including the area from Andover to Salisbury, would be affected by tree and leaf fall. The forecast predicted ‘poor’ adhesion conditions, the second-worst rating on the scale (figure 18).

167 Since no notes or actions from the meeting were required to be recorded, there is no documentary evidence of the risks of the weather forecast being considered during this meeting. Witness evidence indicates that some staff at the meeting were aware that trees and vegetation on the Salisbury line had not been cut back since 2019, and that the MPV run on 31 October 2021 had been postponed. Despite this, no additional reactive mitigation measures were implemented in response to the forecast.

168 The MetDesk weather forecast provided to Network Rail on 29 October 2021 predicted an ‘adverse’ weather hazard on the Wessex outer route. The MetDesk adhesion index forecast for the period from 06:00 hrs 31 October to 06:00 hrs 1 November was emailed to the Wessex autumn controller at 12:31 hrs on 31 October.[22] This predicted ‘red’ (poor) adhesion conditions, the second worst category (figure 18).

169 Network Rail’s Wessex autumn working arrangements stated that the MetDesk information is used in the decision to convene an EWAT and Met Office forecasts are for information. Control room staff at the WICC are only required to take action in response to extremely poor weather actually occurring; they are not required to respond to forecasts of low adhesion. They are only required to respond to low adhesion if they are alerted to it by WSTCF activations, which may be caused by leaf fall railhead contamination, or reports from train drivers or from MOMs inspecting HRLA sites (see paragraph 250).

170 On 31 October 2021, the weather itself did not trigger any extreme weather response and there had been no WSTCF or reports of low adhesion from train drivers. Furthermore, no MOM inspections were carried out on HRLA sites during the weekend of 30/31 October (Wessex autumn working arrangements require regular MOM inspections of HRLA sites), because there was no MOM on duty for the Salisbury area, a known issue (see paragraph 241).

171 Although the impact of the weather on the infrastructure became apparent during the day, not least by virtue of the number of weather-related incidents, the likely implications of the weather on leaf fall and railhead contamination were not identified by any managers within the WICC (see paragraph 250).

[22] RAIB understands that normally the autumn controllers would expect to receive the MetDesk adhesion forecast by 06:00 hrs and that the late delivery on 31 October was due to staffing issues.

The driver's braking point

172 **The driver did not apply train 1L53's brakes sufficiently early on approach to protecting signal SY31 to avoid running onto the junction, given the prevailing levels of wheel/rail adhesion.**

173 The driver of train 1L53 stated that, when signal SY29R displayed a double yellow aspect, he normally used Broken Cross bridge as a visual cue to start braking. Broken Cross bridge is 560 metres beyond signal SY29R and 1,780 metres on approach to signal SY29. It is also 2,560 metres on approach to signal SY31.

174 OTDR and witness evidence suggests that other SWR drivers normally start braking at various locations between Broken Cross bridge and the permissible speed warning indicator for the permanent speed restriction. This is positioned 1,890 metres on approach to signal SY31, meaning that the normal braking point described by the driver of train 1L53 was consistent with the range of those used by other drivers.

175 The driver stated that on the evening of the accident he intended to use the fallen tree and associated debris that he had seen on his earlier journey to London as his marker after which to start braking (paragraph 47 and see paragraph 181). The tree was 250 metres beyond Broken Cross bridge and braking here was also consistent with the range of braking points used by other drivers. However, OTDR data shows that the driver actually applied the brakes approximately 750 metres beyond the location of the fallen tree and associated debris and 1,000 metres beyond Broken Cross bridge, with the train travelling at 86 mph (138 km/h) (figure 35 and see paragraph 189).

176 Analysis of class 159 brake testing data showed that, from this speed and under normal adhesion conditions (that is to say, with the railhead dry and free from significant contamination) and adjusted for the gradient, the train would have stopped in a distance of between approximately 600 and 700 metres using brake step 3. This means that, in the absence of wheel slide, the train would have stopped before it passed signal SY31 if a braking application had been made at either the location of the fallen tree (2,300 metres on approach to signal SY31) or at the actual braking point (1,560 metres on approach to signal SY31).

177 RAIB analysis based on results from the WSP Evaluation Rig (WSPER) testing showed that, given the adhesion conditions on the evening of 31 October 2021, the accident would probably have been avoided if the brakes of train 1L53 had been applied at Broken Cross bridge and, in this case, it is possible that the train would also not have passed signal SY31 at danger. If the brakes had been applied at the fallen tree, around 250 metres beyond Broken Cross bridge, then it is likely that the train would have passed signal SY31 at danger, but it is possible that the collision would have been avoided or occurred at a much lower speed.

178 Before the passage of train 1L53 and the change in railhead conditions as a result of the drizzle that passed over just before it, two earlier trains had stopped at signal SY31, one at 16:29 hrs and the other at 16:45 hrs. Both started braking earlier than train 1L53. The first of these trains, train 1L43 (formed of two three-carriage class 159 units), started to brake before signal SY29R (before the location of the fallen tree) while travelling at 78 mph (126 km/h) and took approximately 3,250 metres to stop. This consisted of approximately 2,050 metres in brake step 1, 80 metres in step 2 and 15 metres in step 3. For the remainder of the distance, train 1L43 was coasting and stopped approximately 30 metres before signal SY31. The weather was dry at this time and, although OTDR data showed that WSP activity occurred, the train was able to stop before the red aspect being shown at signal SY31 (figure 34). The driver of train 1L43 adopted a ‘lighter and longer’ braking technique that they described as normal for them, and something they had been told to do by a former driver instructor. The driver of this train also stated that they were aware of the weather conditions causing some low adhesion during their journey.

179 The last train to encounter signal SY31 showing a red aspect before train 1L53 was train 1L45 (formed of a three-carriage class 159 unit). At 16:45 hrs, when the weather was still dry, the driver of train 1L45 braked shortly before the PSR warning board, beyond the location of the fallen tree, but around 420 metres before the actual braking point of train 1L53, while travelling at 84 mph (135 km/h). Train 1L45 took approximately 1,980 metres to stop. This consisted of approximately 790 metres in brake step 1 and 1,080 metres in brake step 2. For the remainder of the distance, train 1L45 was coasting. Train 1L45 stopped approximately 25 metres on approach to signal SY31. Although the driver of train 1L45 braked later that the driver of the earlier train 1L43, and encountered a greater level of WSP activity, this train was also able to stop before passing signal SY31 (figure 34).

180 After the accident, driver instructors with experience of driving the route on the approach to Salisbury Tunnel Junction stated that, taking into account the environmental conditions on the day, they would have expected a driver who had been told about low adhesion and had received a cautionary aspect at signal SY29R to be making a brake application no later than signal SY29R.

The driver’s braking decision

The driver’s understanding of the adhesion conditions on the day

181 The driver stated that he intended to use the fallen tree and associated debris as his marker after which to start braking, because he believed that the leaves and debris from the tree would create a risk of low adhesion and a risk of the train’s wheels sliding. Wheel slide is undesirable in itself because it can cause flat spots on train wheels. The driver stated that he was aware that the formation of the train was shorter than normal, and that this would affect the train’s braking capabilities,[23] but that he believed there was still sufficient braking distance beyond the tree debris, and up to the point where he actually braked, to stop before passing signal SY31 (paragraph 175 and see paragraph 213).

[23] In accordance with the SWR professional driving policy SWR train drivers are required to know how shorter train formations can affect the performance of train braking and adapt their driving and braking technique accordingly. Longer trains generally have better braking performance in low adhesion conditions due to the additional conditioning of the railhead by the increased number of wheels. Also, trains operating in multiple have more braked axles and additional sanders.

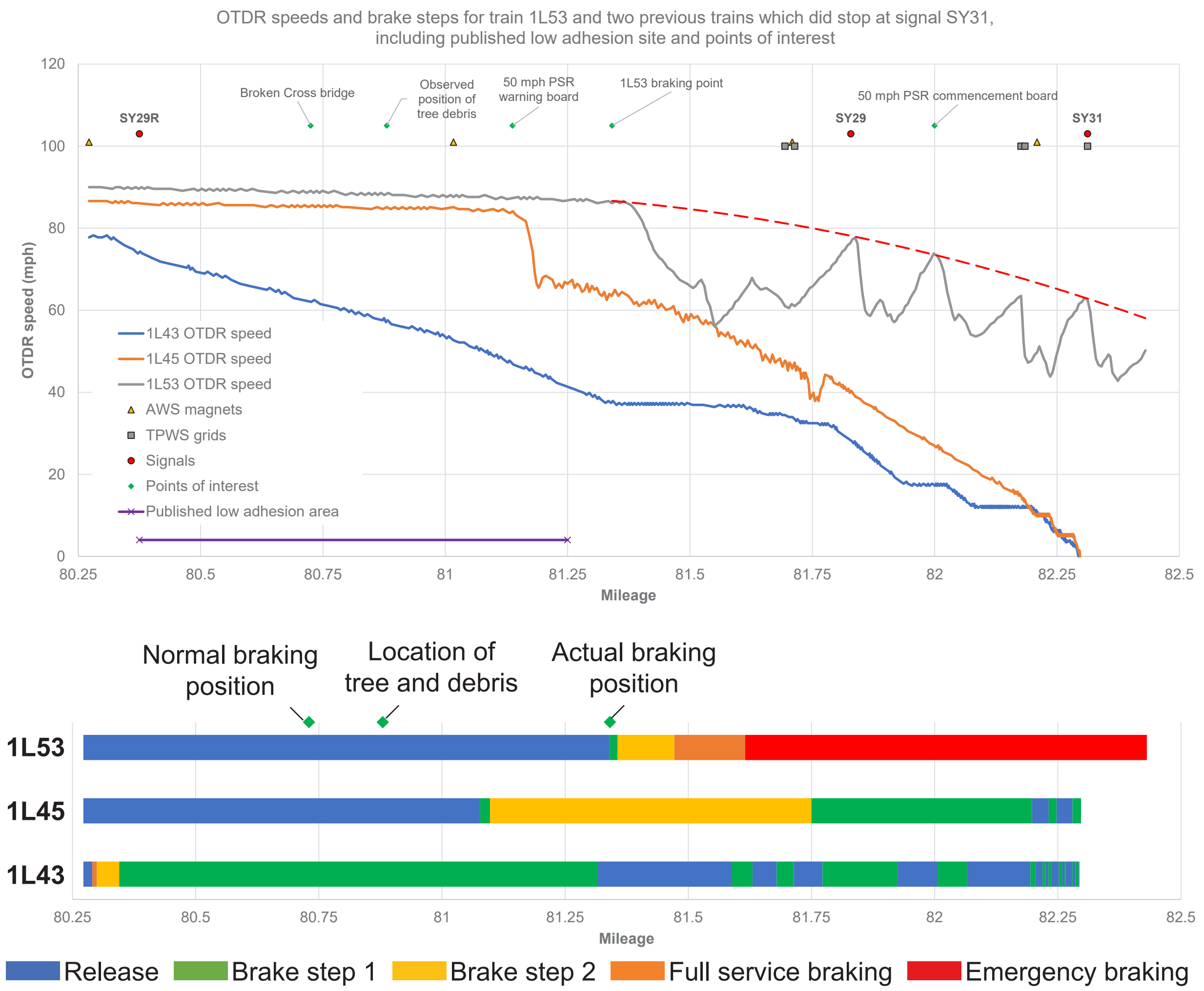

Figure 34: Speeds for trains 1L43 (blue), 1L45 (orange) and 1L53 (grey) as recorded by their respective OTDRs, and important locations. The red dashed line indicates an approximation of train 1L53's 'ground speed'. The OTDR has recorded the measured wheel as travelling more slowly because it is sliding. A similar but less pronounced effect can be seen during part of train 1L45's data. Braking techniques employed by train drivers of trains 1L43,1L45 and 1L53 are shown in the graph below.

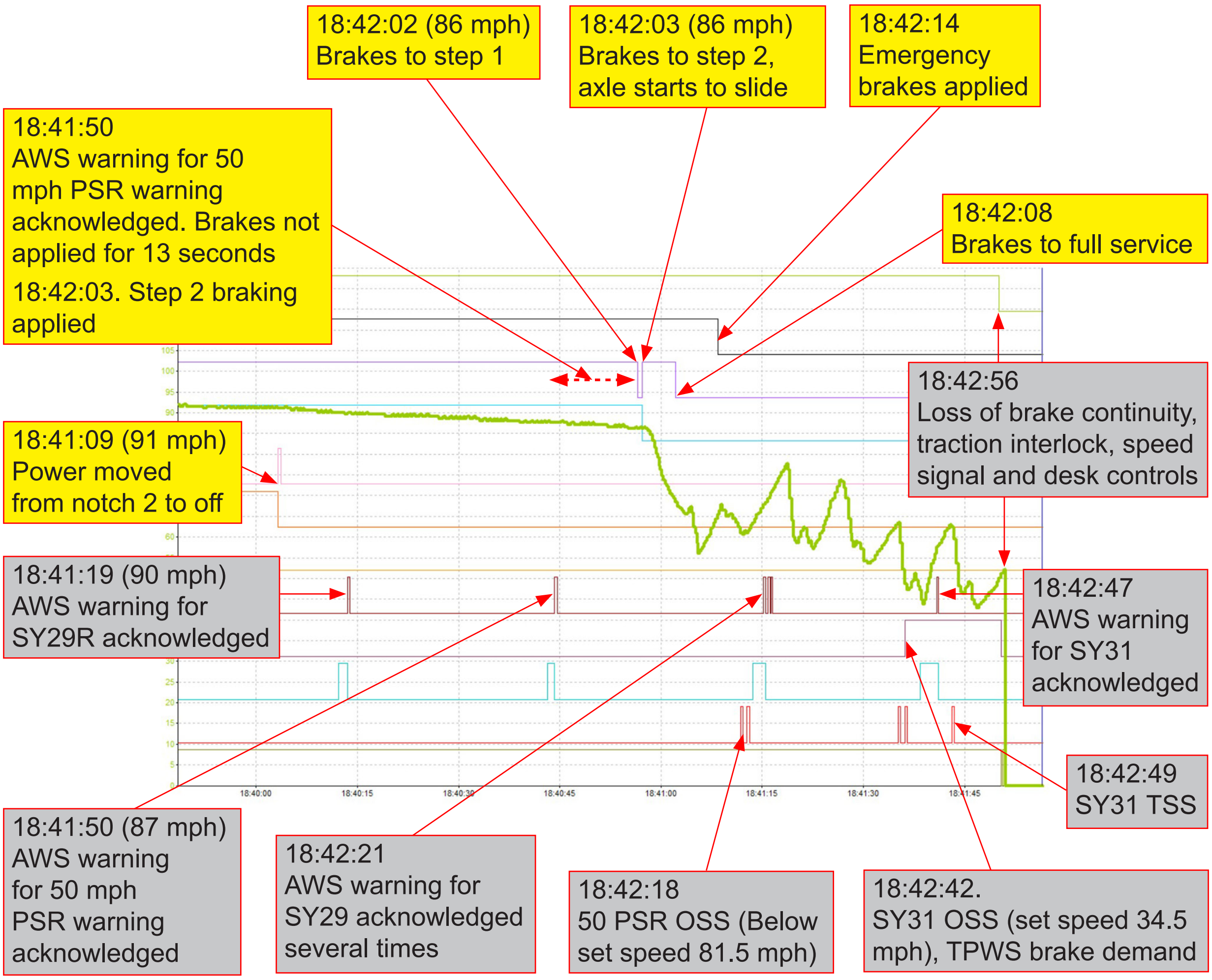

Figure 35: Annotated OTDR trace from train 1L53 showing braking and AWS/TPWS activations and acknowledgements.

182 Other than the fallen tree, the driver's understanding was that adhesion elsewhere in the area was unremarkable and, as such, he did not need to drive more defensively (paragraph 53). There was, however, information available to him that could have raised a concern about low adhesion. This information included weather reports, incorporating the poor adhesion forecast, which were posted at Salisbury depot where the driver booked on for duty (paragraph 96). However, the driver of train 1L53 and other drivers told RAIB that they did not routinely check or look at these forecasts because they felt they did not have time to do so and that they found the weather notices too detailed and difficult to understand.[24] They therefore relied on their own experience and visual observations when driving to understand the prevailing adhesion conditions. This was the case with the driver of train 1L53 on the day of the accident and was his normal approach.

[24] The weather notices were simplified to their current format around 2014. SWR driver diagrams generally allow 16 minutes booking-on time, of which 10 minutes is provided for reading notices and briefing material.

183 In addition to the weather notices, another driver warned the driver of train 1L53 about the poor adhesion conditions on the Down Main line approaching Salisbury. It is also possible that a different driver warned him of the general poor weather conditions on the route (paragraph 51). As the driver had never previously experienced problems in that area and had not knowingly encountered any low adhesion on the journeys to and from London until the approach to Salisbury Tunnel Junction, these reports of low adhesion were not a factor in his decision to delay his braking until beyond the fallen tree and associated debris.

184 There were other potential opportunities to raise the driver's awareness of low adhesion in the area which were not taken. If staff at the WICC receive intelligence about low adhesion, such as from driver's reports of low adhesion (ROLA), WSTCF or MOM inspections, then control staff can arrange for signallers and the WICC to warn drivers by sending messages over the GSM-R train radio system.

185 Witness and OTDR evidence shows that several other trains had encountered low adhesion on the Down Main line between signals SY29R and SY31 on the afternoon and evening of 31 October, and the drivers of these trains had observed signs of wheel slide occurring. However, none of the drivers made a report of low adhesion to the signaller. There were also no WSTCF reports and no MOM inspections.

Signal spacing

186 The signalling on the approach to Salisbury Tunnel Junction provides an excessive braking distance for passenger trains between signals SY29R and SY31 (figure 36). Excessive braking distances mean that drivers must delay full braking beyond the double yellow aspect signal, otherwise they could stop short of the red signal and/or incur time delays on their journey.

187 The applicable Rail Industry Standard in force at the time of the accident, RIS-0703-CCS, 'Signalling Layout and Signal Aspect Sequence Requirements' (issue 1.1, March 2018) states that it is good practice for signal spacing to provide between 110% and 150% of the required braking distance. The spacing between signals SY29R and SY31 provides approximately 190% of the minimum required braking distance.

188 The signalling at Salisbury Tunnel Junction substantially pre-dates standard NR/L2/SIG/30009/D220 which states: '*If the distance is significantly greater than the minimum then this may lead to drivers continuing at the permissible speed and trying to judge when to brake with the risk of SPAD, or braking early and coasting leading to an increase in journey time or loss of capacity'.* As such, the over-long spacing between cautionary and danger aspects on the Down Main line enables drivers to decide how far beyond the cautionary aspect to start braking and increases the possibility of situational awareness loss.

The driver's actual braking point

189 The driver decided to use the fallen tree as his marker after which he would start braking. This was located 250 metres beyond his normal braking point of Broken Cross bridge. However, the driver did not then start braking until around 1,000 metres beyond this bridge (paragraph 175).

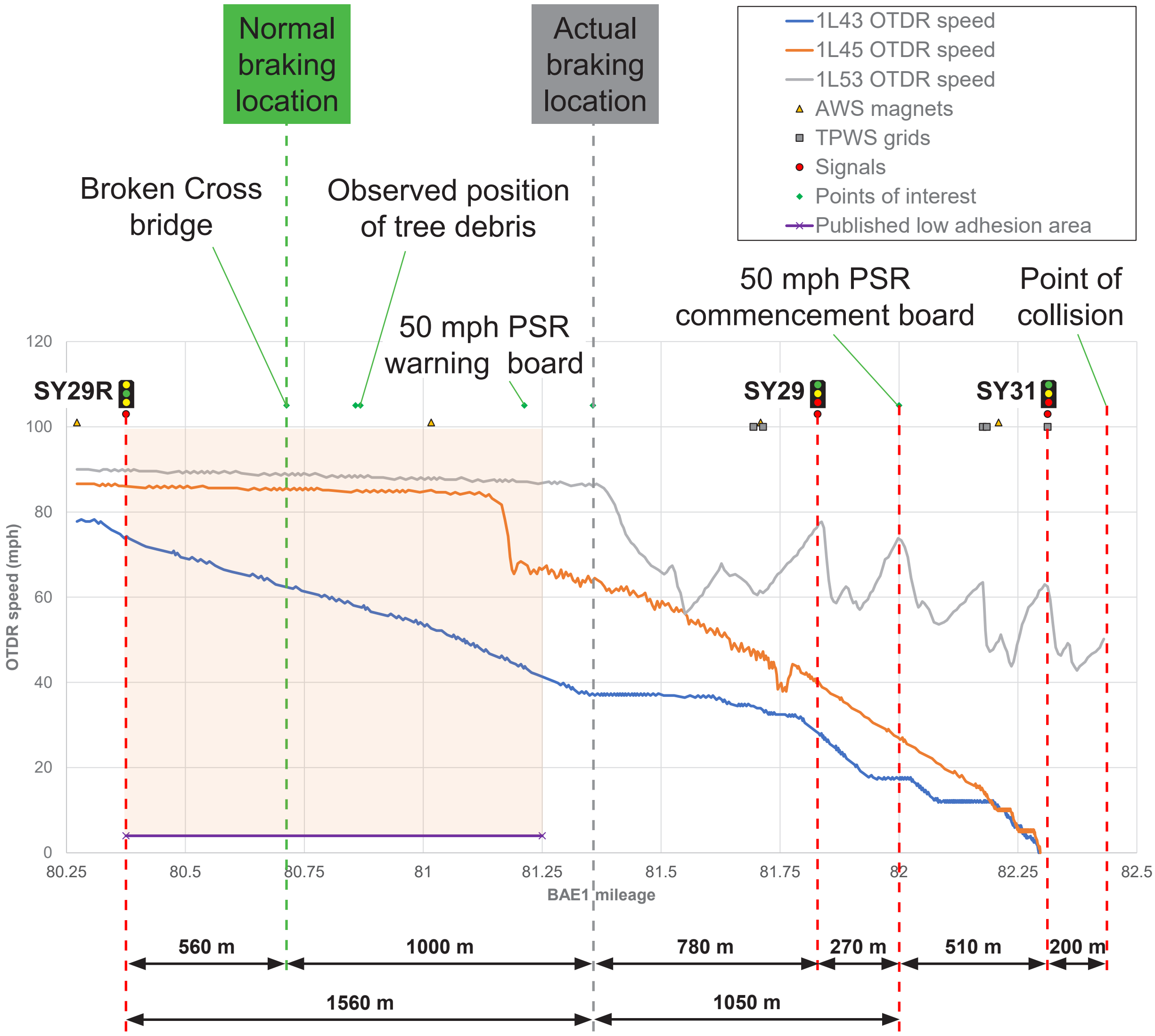

Figure 36: Annotated OTDR traces from trains 1L43, 1L45 and 1L53 showing important locations and distances.

190 Witness evidence indicates that the driver did not brake until this point because he had not recognised that he had passed the fallen tree. Although RAIB cannot be certain from the available evidence how accurate the driver's appreciation was of the fallen tree's location, he had specifically been looking for the fallen tree on his journey up to London earlier in the day, having been previously told about it. In addition, he was a very experienced driver who had been driving the route for many years, and the fallen tree was in close proximity to significant structures, signal SY29R followed by Broken Cross bridge. RAIB has therefore concluded that the driver would have had a reasonable appreciation of the fallen tree's location.

191 Although the available evidence cannot conclusively explain why the driver did not recognise the location of the fallen tree, RAIB considers that the two most likely explanations are that he did not see the tree (even though he was looking for it), or that he lost awareness of the driving task. It cannot be known how conspicuous the fallen tree was to the driver of train 1L53 in the dark, with the train travelling at 86 mph (138 km/h). However, the tree remnants were close to the line and on the driver's side and are visible in FFCCTV images (figure 37), although RAIB recognises that a driver's actual view of objects may differ from that shown in CCTV images.

Visual cues

192 It is possible that the driver, despite consciously looking for the fallen tree and associated debris, did not see it because it was not sufficiently conspicuous in the environment on that evening. RAIB examined and tested the unit involved and has ruled out any impairment of the forward view, such as a fault with the train's windscreen, wash/wipe or headlights which may have contributed to the driver not seeing the tree.

Figure 37: (Main photograph) Image taken from train 1L53 FFCCTV system showing the tree debris as train 1L53 passed by. (Inset) Daylight image showing the condition of the tree and debris when train 1L52 passed by on the Up line to London Waterloo.

193 In May 2022, RAIB undertook a reconstruction in daylight and in darkness to understand the visual cues and other environmental influences present when driving a train towards Salisbury Tunnel Junction. This showed that the section of line approaching and beyond Broken Cross bridge is largely dark at night, with little artificial light available from streetlights or buildings. Consequently, there are few visual cues for a driver regarding their position after they have passed Broken Cross bridge until they start to approach signal SY29; it is a dark 'tunnel' created by the vegetation and tree canopies, only illuminated by the train's headlights.

194 Signal SY29 is approached around a left-hand curve after a straight section of railway. Along this straight section, there is an increase in artificial lighting from streetlights as the train approaches the outskirts of Salisbury, as well as a local garage forecourt and a supermarket car park (figure 38). The light cast from the signal aspect at signal SY29 can also be visible, reflecting on the rails, although on the evening of the accident the reflection from the railhead may have been limited due to the railhead contamination.

195 Witness evidence is that the driver of train 1L53 decided to start braking when he believed he would be at risk of passing signal SY31 at red if he delayed braking any further and that this was before signal SY29 came into view. The location where he started braking coincided with the appearance of the visual cues described above. RAIB has concluded that it was these cues that probably prompted the driver to his location and caused him to apply the train's brakes.

Figure 38: RAIB reconstruction showing the environment on approach to signal SY29: (left) 798 metres from signal SY29; (centre-enhanced) reflection from lighting from signal SY29 at danger on the railhead; and (right) 773 metres from signal SY29 with street lighting and car forecourt lighting visible.

Driver awareness

196 Given the proximity of the tree to the railway, the time that elapsed between the train passing the fallen tree and the driver braking, and the limited use of train controls during this period, it is also possible that the driver did not see the fallen tree because he experienced a temporary loss of awareness of the driving task.

197 Evidence from the train's OTDR shows that the driver acknowledged the AWS horn for the permissible speed warning indicator which was located 290 metres (8 seconds) beyond the fallen tree and 540 metres beyond Broken Cross bridge. Around 12 seconds later, when the train was around 1000 metres from Broken Cross bridge and travelling at 86 mph (138 km/h), the driver started applying the train's brakes.

198 Although the driver's acknowledgement of the AWS horn may imply some awareness of the driving task, research[25] has shown that such responses can be automatic with little conscious awareness.

199 As described in paragraph 195, the location where the driver started braking coincided with the appearance of the artificial lighting from streetlights, a local garage forecourt and a supermarket car park. In this scenario, it may have been these visual cues which caused him to become aware of the driving task again, and start to brake.

[25] McLeod, RW, Walker, GH and Mills, A (2005), 'Assessing the human factors risks in extending the use of AWS'. In J. Wilson, B. Norris and A. Mills (Eds.), Rail Human Factors: Supporting the Integrated Railway. London: Routledge.

200 As the driver was over 63 years old, he was subject to an annual medical examination in accordance with RIS-3451-TOM, ‘Train Drivers – Suitability and Medical Fitness Requirements’ (issue 1, dated December 2016). This standard requires that medical examinations are carried out by, or under the supervision of, a registered medical practitioner. Medical examinations include:

- a general health assessment to identify any health conditions or medications that could cause sudden loss of consciousness, a reduction in attention or concentration, sudden incapacity or a loss of balance or co-ordination
- vision tests, including colour vision and diseases of the eye, and hearing
- blood or urine tests to detect diabetes mellitus and other conditions, and the presence of drugs of abuse
- an electrocardiograph examination to check the heart’s rhythm and electrical activity.

201 RAIB has found no evidence of distraction from electronic devices or the cab environment. Post-accident toxicology did not identify the presence of any drugs or alcohol. RAIB has also found no evidence from the driver’s roster or sleep pattern, or any medical evidence of a sleep disorder, to suggest that he may have been suffering from fatigue.

202 RAIB also found no evidence of any pre-existing medical condition or medical treatment that could have caused a temporary loss of awareness or that might have affected the driver’s perception, memory, or attention, although the presence of an unknown medical condition of this nature cannot be entirely discounted.

The train’s braking systems

203 **The braking systems of train 1L53 were unable to mitigate the effects of the prevailing wheel/rail adhesion conditions.**

204 RAIB’s investigation considered the capability of the train’s braking and sanding systems to cope with the low adhesion conditions at the time of the accident.

205 Maintenance records for unit 159102 were up to date and no defects relevant to the accident were present. The last scheduled test of the brakes and sanding systems was conducted on 26 September 2021. On this occasion, a sand discharge test was conducted. A container is placed beneath the sand discharge nozzles, and a test button pressed for 30 seconds. The sand discharged into the container is then weighed. The range of acceptable weights, as defined by the vehicle maintenance instruction, is 0.6 kg to 1.0 kg. The values recorded for the nozzles on 57803 (the carriage leading at the time of the accident, and hence actively sanding) were 0.617 kg (left side nozzle in direction of travel) and 0.752 kg (right side nozzle). All other brake system air pressures were found to be within acceptable limits.

206 Overnight from 29 October into 30 October, 159102 had a fuel point examination at Salisbury depot. During that examination, the sandboxes were topped up. Records show that 52803 had four bags of sand added, and 57803 had one bag of sand added. This indicates that, before that examination, the sanding system had been operative and discharging sand. SWR staff found no faults with the sanding system during train preparation on the day of the accident.

207 RAIB has therefore concluded that the maintenance and preparation of the train were unlikely to have had any influence on the accident.[26]

208 RAIB tested the sanding equipment fitted to carriage 57803, the leading carriage of train 1L53 during the accident, as far as was possible following the accident, although the extent of this testing was limited due to the damage caused by the collision. Testing also took place following recovery activity, which may also have affected the status of systems.

209 As part of this testing, it was established that the electrical controls of the sanding system were fully operational, and that the system was not pneumatically isolated. Clean, dry sand of the correct type was found to be present in the sandbox. Accident damage meant that it was not possible to confirm the alignment of the leading sanding nozzles with respect to the wheel/rail interface. It was also not possible to eliminate the possibility of a blockage in the sand delivery pipework that was dislodged during the collision and recovery. However, this pipework was examined by RAIB and found to be unobstructed.

210 The operation of the pneumatic system which forms part of the sanding equipment could also not be tested, as the unit's engines could not be started. However, given that the air system feeding the sanders is very simple, and was apparently functioning correctly before the accident, it is considered unlikely by RAIB that an undetected pneumatic system fault existed.

211 Railway Group Standard GMRT2045 'Compatibility Requirements for Braking Systems of Rail Vehicles' (issue 4, March 2016) states that the maximum distance in which a three-carriage class 159 DMU should be able to stop in normal adhesion conditions on level track from a speed of 85 mph (136 km/h) is approximately 822 metres using full service (step 3) braking.

212 In February 2022, SWR carried out a series of brake tests using a three-carriage class 159 unit running between Basingstoke and Salisbury on the Down Main line approaching signal SY31. When adjusted for the gradient on the section of track, the results of these tests showed that a train of the same type and configuration as train 1L53 would be compliant to GM/RT2045.

213 On 22 December 2022, further tests were carried out by SWR using a three-carriage class 159 unit on the Down Main line approaching signal SY31. The weather conditions during these tests were overcast with light rain, and the brakes were applied from similar speeds and locations as used by the driver of train 1L53 on 31 October 2021. No railhead contamination was reported and no WSP activity was recorded during the tests and the train was able to stop on approach to signal SY31.

214 The driver of train 1L53 first applied the brakes at step 1, then almost immediately step 2, when the train was 1,560 metres on approach to signal SY31. After travelling another 210 metres, the driver increased the level of braking to step 3 (full service). The collision with train 1F30 occurred 1,760 metres from the point where the driver had first applied the brakes (figure 36). This shows that the braking distances achieved by the train during the accident exceeded both the maximum range set out in standard GMRT2045 and those achieved during SWR's post-accident tests.

[26] Post-accident wheelset checks for train 1L53 were completed and no contamination or damage was identified.

215 Data from train 1L53 showed that the WSP system was active on all three carriages of the train from 18:42:04 hrs until the time of the collision at 18:42:56 hrs. Analysis of railhead samples taken after the accident found the presence of silica (a component of sand) which showed that trains, likely including train 1L53, had been discharging sand from on approach to signal SY29 through to after signal SY31 (paragraph 132).

216 RAIB recovered the WSP equipment from train 1L53 (unit 159102). No defects or abnormalities were found in the operation of the WSP components when tested by RAIB. A detailed laboratory examination of this equipment was completed using the WSPER (WSP Evaluation Rig) system. This showed that the WSP system operated as expected for equipment of its age and type, and that its performance was consistent with that recorded when it was originally approved for use in 2006. Although the system was not fully compliant with the current guidance[27] (which is not applicable retrospectively), there is no evidence to suggest that this non-compliance affected the causes or the outcome of the accident.

217 The tests undertaken by SWR during dry and light rain conditions demonstrated that a train of the same type and configuration as train 1L53 would have been capable of stopping within the braking distances set out in standard GMRT2045 under normal adhesion conditions. The braking distances actually achieved by train 1L53 indicate that the WSP and sanding systems on the train were unable to mitigate the very low wheel/rail adhesion encountered on 31 October 2021 (paragraphs 130 and 131).

218 The WSPER system was also used to approximate the braking performance of six-carriage and nine-carriage class 159 formations. This analysis assumed that the first three carriages would encounter similar adhesion levels to that derived from train 1L53, but that subsequent carriages would encounter slightly higher levels of adhesion. This would be due to the passage of previous wheelsets modifying the available adhesion and the application of sand by the preceding three-carriage vehicles in the train. A six-carriage class 159 unit would discharge sand from the leading and fourth carriages; a nine-carriage train from the leading, fourth and seventh carriages. Using WSPER, it was possible to store the data of the modified adhesion conditions from each run and then apply this modified set to the next test, which started from a slightly enhanced level of adhesion.

219 The results obtained from these tests suggest that neither a six-carriage nor a nine-carriage formation braking from the same location as train 1L53 on the night of the accident would have been able to stop before the collision point, assuming they had encountered the same initial wheel/rail conditions.

[27] GMGN2695 'Guidance on Testing of Wheel Slide Protection Systems Fitted on Rail Vehicles', issue 1, December 2010.

220 The type of sanding system fitted to train 1L53 injects sand at a fixed rate under both wheels of the third wheelset from the front of the leading carriage. When braking, this sanding system is controlled by the train's WSP system (paragraph 41). Research in the UK by RSSB has shown that enhanced sanding systems are able to improve adhesion beyond that provided by a single fixed rate sander, such as that fitted to train 1L53. Enhanced sanding systems include distributed sanding, where more than one axle is equipped with sanders, and variable rate sanding, where higher quantities of sand are delivered at higher train speeds. Enhanced sanding can achieve a significant reduction of a train's stopping distance in reduced adhesion conditions, with the largest benefit being achieved by variable rate sanders at two axles, known as double variable rate sanding.

221 RSSB research illustrates the potential benefits of enhanced sanding systems, as shown in figure 39. RAIB has undertaken a simple analysis, using the underlying data from the RSSB research, to estimate the effect if train 1L53 had been fitted with a DVRS system. The higher sand delivery rates of a DVRS system would certainly have provided better low adhesion braking performance, which would have led to a reduced collision speed. Although it is not possible to be certain of the actual benefits of DVRS in the specific circumstances of this accident, the analysis undertaken by RAIB suggests that it is probable that the collision would have been avoided altogether. The analysis also suggests that it is possible that a DVRS equipped train would not have passed signal SY31.

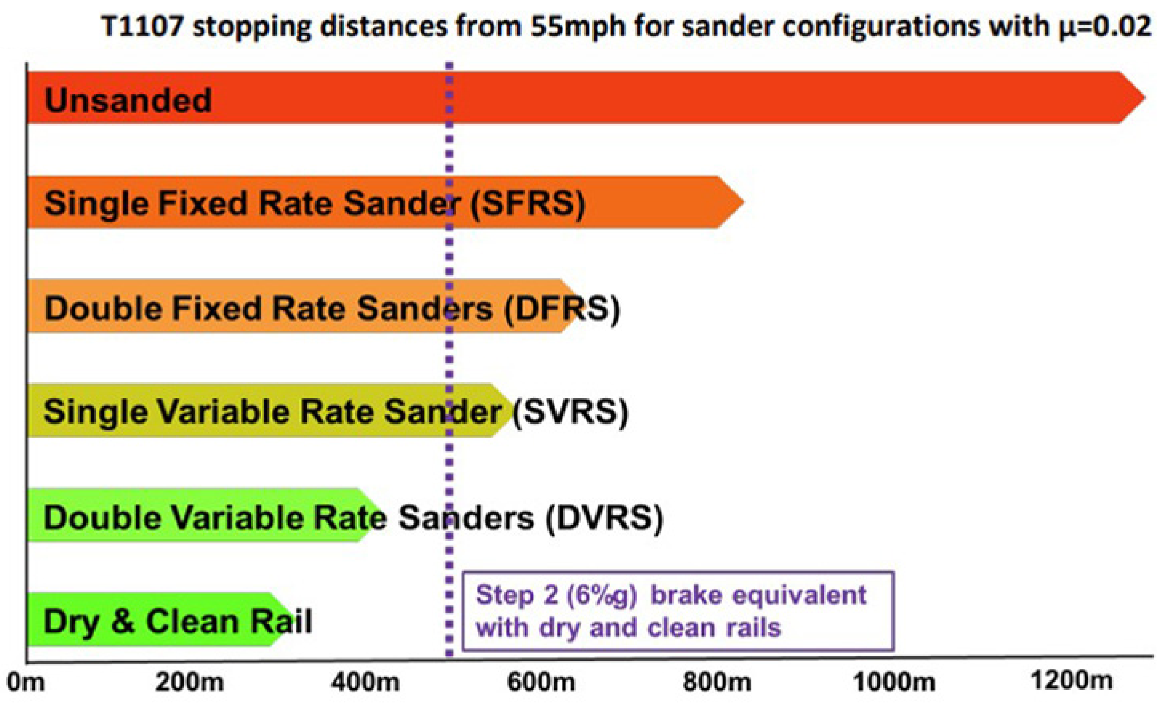

Figure 39: Diagram from RSSB research project T1107 showing the potential benefits of variable rate sanding systems.

Identification of underlying factors

Management of low adhesion risk

222 **Network Rail's Wessex route did not effectively manage the risks of low adhesion associated with the leaf fall season. This was a probable underlying factor.**

223 Documentary and witness evidence shows that before the accident Network Rail's Wessex route had not correctly identified sections of track as HRLA sites. This was probably because the information (figure 40) that the SDS was provided with and which they were using to identify such locations was inaccurate. These inaccuracies arose because the process employed to inspect and risk assess locations, and the subsequent dissemination of the information gathered, was ineffective (paragraph 136).

224 Even if Network Rail's Wessex route had identified the discrepancies with the information, and the SDS had been able to appropriately identify the HRLA sites, RAIB considers it unlikely that the route would have taken suitable action to manage the associated risk. This was because there were several barriers to effective low adhesion risk management present within the route. These included issues relating to:

- resourcing (paragraph 225)
- liaison between departments (paragraph 231)
- track access constraints (paragraph 237)
- MOM inspections (paragraph 241)
- understanding of railhead treatment effectiveness (paragraph 243)
- weather response standards (paragraph 250)
- staff competences (paragraph 253).

Resourcing

Off track

225 Within Network Rail Southern region, off track asset management is a regional role, supporting its Kent and Sussex routes, as well as the Wessex route. However, at the time of the accident the role was vacant. Witnesses described how the responsibilities for off track asset management within Wessex route were being undertaken by the SAE, which led to a lack of strategic leadership in relation to developing a vegetation management plan and co-ordinating activities between Wessex operations and maintenance off track staff.

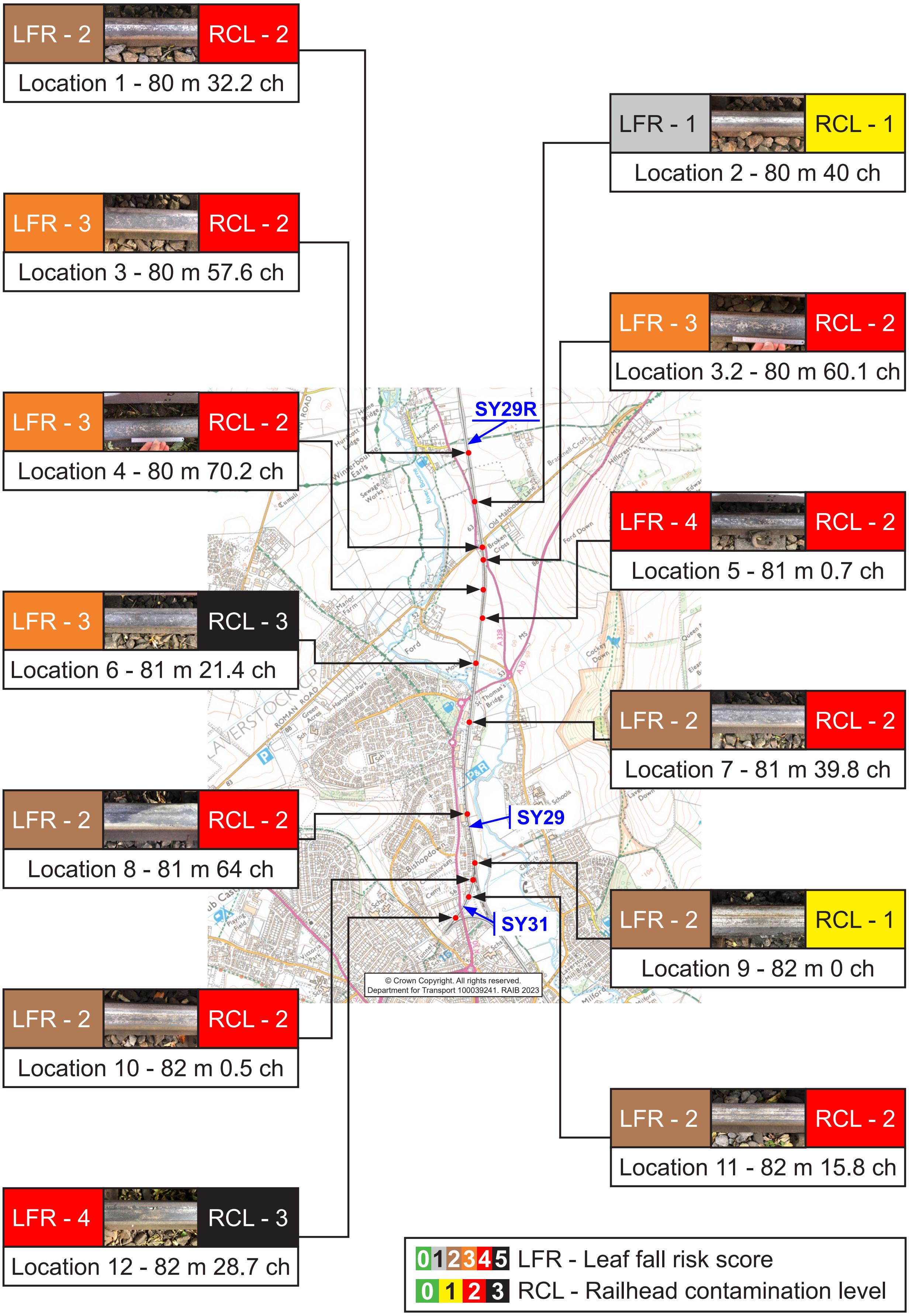

Figure 40: Braking locations for train 1L53 with predicted leaf fall risk scores (0 to 5) from the leaf fall assessment completed in June 2021 and corresponding physical railhead contamination level found on site (0 to 3) on 31 October 2021.

226 A level 2 audit was carried out on Network Rail's Wessex outer route MDU between January and March 2021 which highlighted observations and non-compliances with the requirements of NR/L2/OTK/5201 (paragraph 112). As a result of the audit process, in February 2021, the SAE asked the off track section manager within Wessex outer MDU to address the excessive vegetation growth on the Up and Down Main lines at Salisbury. In June 2021, the off track section manager reported that, although the COVID-19 pandemic had restricted visual on-foot assessments of lineside vegetation, cab ride video assessment of lineside vegetation would still be completed (paragraph 152). The section manager reported that although vegetation growth was identified, this related to work that had previously been identified and reprioritised.

227 Despite this report, MDU off track staff reported that its increasing workload combined with a shortage of resources between May and August 2021 (figure 41) meant that it could not address the existing work bank and that the MDU was 'firefighting' in response to arising incidents. Additionally, witness evidence is that there was also a perceived problem with the availability of contractors. Consequently, the MDU did not have the time or resources to prioritise and plan the vegetation assessment and management work.

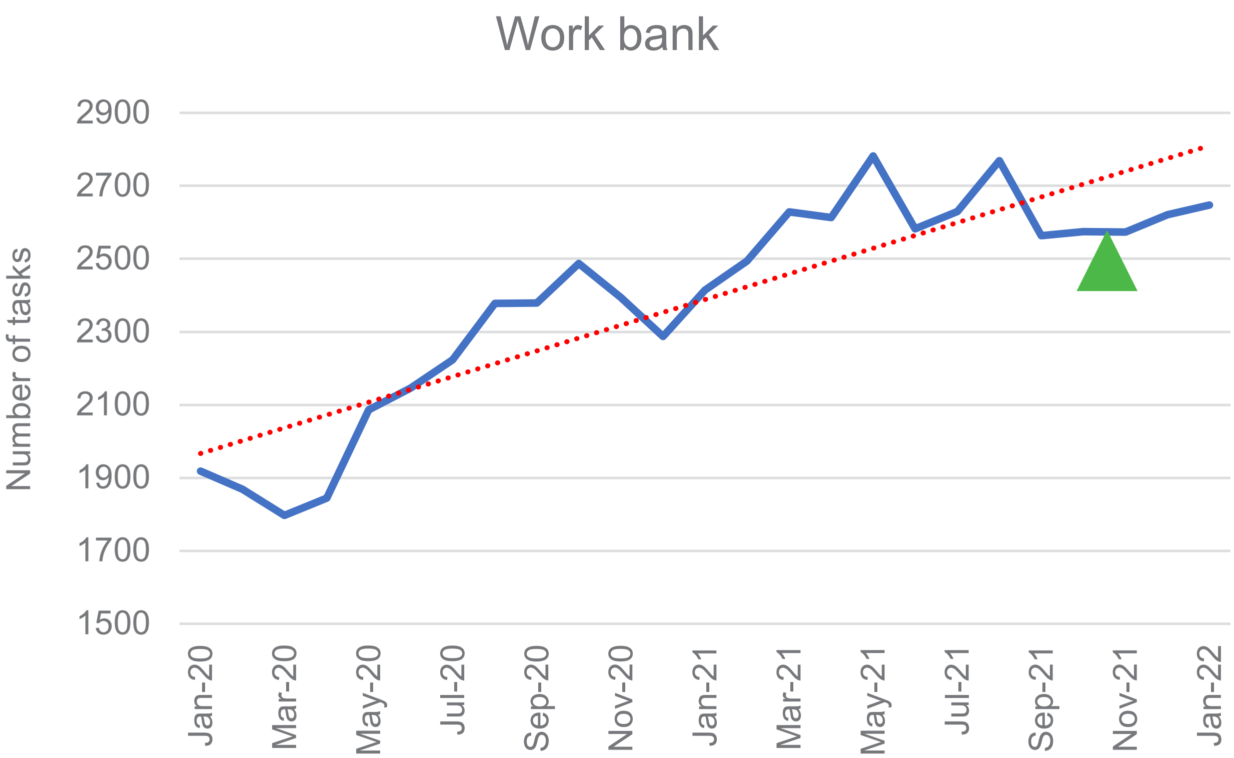

Figure 41: Ellipse work bank (number of tasks) levels (blue solid line) and mean average level (red dotted line) between January 2020 and January 2022 (green triangle shows accident date).

228 Before the accident, the off track section manager discussed the competence, workload and resource issues with the off track TME. The off track TME subsequently wrote a paper to Network Rail's Wessex route infrastructure management team highlighting the significant increase in the MDU off track section's workload since 2020. This paper also noted that the lack of competences held by permanent staff, such as working at heights, using rope access and use of chainsaws, and the lack of resource was creating a risk of non-compliance with Network Rail's standards, as highlighted by the 2021 audit. Despite this, no action was taken by Wessex route to address the points raised and the Ellipse data suggests that the off track section continued to see high workloads until around August 2021.

Seasons delivery specialist (SDS)

229 During 2020 and 2021, the SDS realised they were struggling with workload and that management of the autumn process could not be undertaken by one person alone. This problem had also been identified by one of their predecessors in 2017. This predecessor prepared a proposal to increase the number of seasons delivery staff to mitigate the risks of relying on a single, relatively junior member of staff. Neither Network Rail's Wessex route nor South Western Railway operations departments formally responded to the proposal, although a lack of budget for the new roles was stated in a subsequent conversation as a reason for not pursuing the new roles.

230 In July 2021, the SDS was successful in obtaining the secondment of extra staff into the WICC to operate an autumn control desk (paragraph 110). Four staff were seconded to work early and late shifts from September to December 2021. However, due to the number of incidents that occurred on the morning of 31 October, the members of staff on the autumn control desk were diverted from their responsibilities to help the WICC manage the incidents.

Liaison between departments

231 The management of autumn preparedness requires planning and co-ordination between Network Rail's operations and off track functions (figure 42). As outlined below, witness and documentary evidence show there was no apparent strategy to promote collaboration between these departments to manage leaf fall risk. This led to what witnesses described as a 'silo' culture within Network Rail's Wessex route, with very little co-ordination between, or information shared across, these functions. This was an issue which was also identified by the Office of Rail and Road (ORR) in 2020 (see paragraphs 299 to 305).

232 Network Rail has two principal standards relating to autumn preparedness. These deal with vegetation management (NR/L2/OTK/5201) and operations (NR/L2/OPS/095). The operations standard was amended in June 2019 to align it with the maintenance activities in the vegetation management standard. However, despite this, the standards do not promote liaison between the two functions or mandate the sharing of information needed to support development and implementation of the autumn working arrangements.

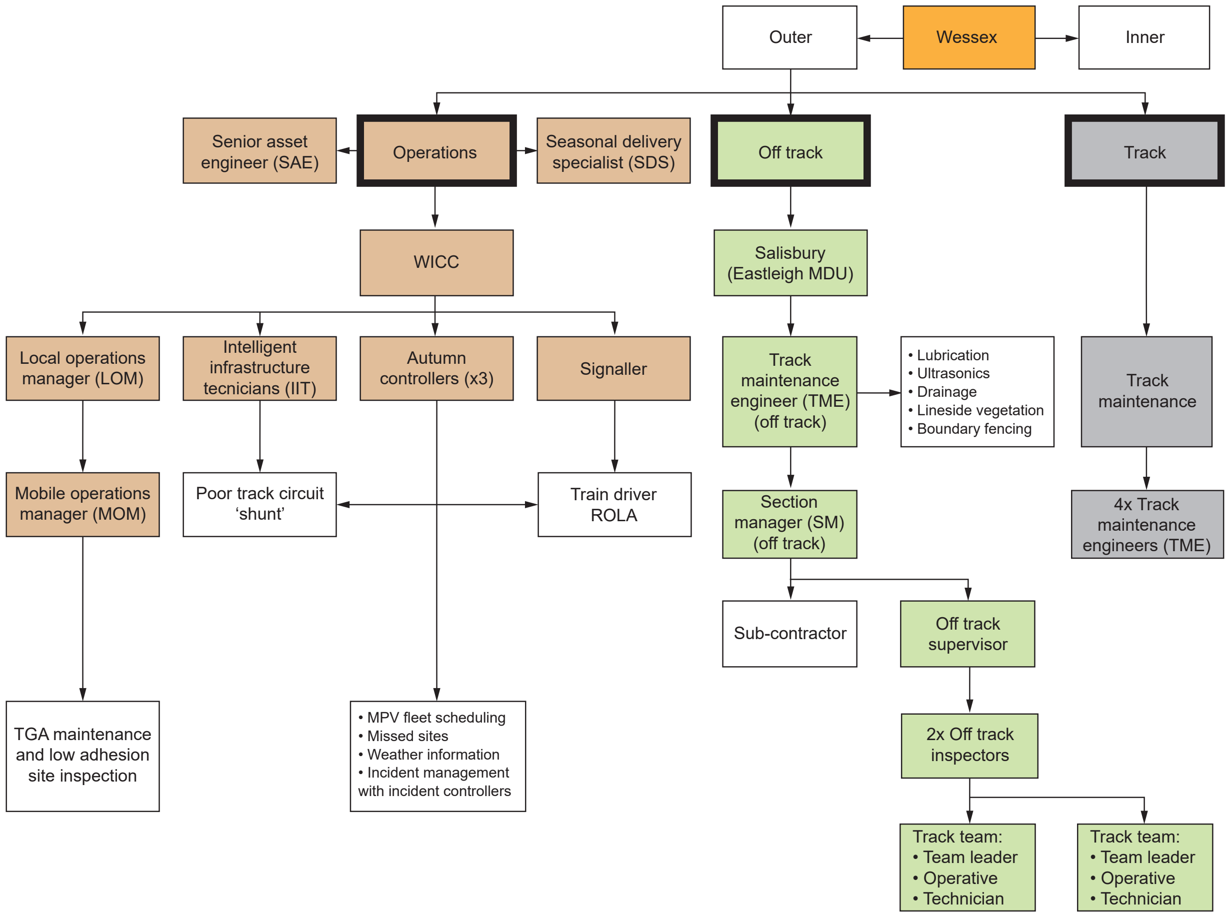

Figure 42: Network Rail's Wessex route departments involved with the co-ordination, planning, maintenance and response to autumn.

233 Witness and documentary evidence show that very little co-ordination took place between the SDS and the relevant MDU off track section managers in the preparation of the autumn working arrangements document for 2021. If the collaboration had been effective, it might have become apparent to the SDS that MDU off track staff had not implemented any actions to mitigate the leaf fall risk and had repeatedly deferred other vegetation management actions since 2018.

234 Although the MDU off track had video footage of the vegetation growth since 2019, this had not been shared with the SDS. This meant that the SDS had little awareness of the nature and status of the risk or risk mitigation measures relevant to the vegetation on the Up and Down Main lines and other lines within Wessex route. Likewise, the MDU off track staff had little appreciation of the importance of the intelligence they had gathered about the condition of the vegetation and trees to the leaf fall risk being managed by the SDS. Furthermore, the MDU off track staff were not using information that was available from the SDS to help them appropriately assess and prioritise the work that was required to manage the risk from lineside trees and vegetation (paragraph 151).

235 Although the audit of the MDU undertaken in 2021 highlighted non-compliances with Network Rail standards, the report did not recognise any issues of concern with the relationship between the SDS and the MDU off track staff, as this liaison is not required by the standard (paragraph 112).

236 Witness evidence also shows that the lack of technical training, competence management and non-technical skills training associated with the role of the SDS was a factor in the SDS not appreciating the importance of engaging with staff in other departments (see paragraph 253).

Track access

237 From June 2021, after the fatal track worker accidents at Margam (RAIB report 11/2020) and Surbiton (RAIB report 05/2022), Network Rail implemented safety measures to restrict some forms of track access. The track access constraints affected both the maintenance of vegetation and the assessment of HRLA sites. Due to the topography of the Up and Down Main lines at Salisbury and locations where limited clearance increased the risk to track workers, both MDU off track staff and MOMs were required to obtain line blockages to inspect and maintain the line.

238 When the SAE asked the off track section manager to address the excessive vegetation growth on the Up and Down Main lines at Salisbury in February 2021 (paragraph 226), the off track section manager reported that the complexity of the lines made track access difficult, so it was not possible to schedule such a maintenance task to inspect or cut back the vegetation.

239 The Wessex route autumn working arrangements document required a MOM to undertake regular inspections[28] of HRLA sites for railhead contamination and to submit inspection forms and images for review by the autumn controller or the SDS. The objective of these regular inspections is to proactively monitor levels of contamination at the sites and, if significant contamination is identified, to arrange for additional treatment to be undertaken. MOMs are also required to respond to reports of WSTCF activations and low adhesion.

240 However, direct access to the track to allow these MOM inspections of HRLA sites was restricted because of the limited availability of line blockages. This meant that MOMs were required to make railhead observations to identify contamination from vantage points such as fences and bridges. In July 2021, MOMs within Network Rail's Wessex route challenged the decision with their line managers about the adequacy of the process of carrying out inspections from a vantage point, because this was seen to be ineffective due to the length of track to be inspected and limited sighting that was available (figure 43). However, MOMs were instructed to continue with the current process of inspection. RAIB is unaware of any action taken in response to these challenges.

MOM inspections

241 As well as restrictions on track access, the process of using MOMs to inspect for railhead contamination within Network Rail's Wessex route appears to have been ad hoc. This was because there was no guarantee that a MOM would be available at any given time, due to the requirement for them to respond to other operating incidents. This was exacerbated by the lack of MOM resources within the Wessex route.

[28] Witness evidence indicates that the expectation was that MOM inspections of HRLA sites would be undertaken on a daily basis by the early or late rostered MOMs.

Figure 43: Image taken from a vantage point by a Network Rail MOM inspecting an HRLA site (post-vegetation clearance).

242 Witness and electronic evidence shows that, before the accident, HRLA inspections by MOMs were only being sporadically undertaken for the reasons given above. Furthermore, witness and documentary evidence shows that the inspection forms and images that were being submitted were not being reviewed in accordance with the Wessex route autumn working arrangements document. The SDS was unable to explain why the review process was not being followed.

Understanding of railhead treatment effectiveness

243 Network Rail's Wessex route adopted 60 mph (96 km/h) as the standard speed for its railhead treatment vehicles. Witness evidence shows that this decision on treatment speed was due to the number of route miles needing to be covered, the resources required to staff the MPV and the water refilling opportunities.

244 In 2006, RSSB and the rail industry AWG sponsored research, including testing, into low railhead adhesion, its prevention, and the mitigation of associated risks (paragraph 83). This was after the incidents at Lewes and Esher in 2005 (RAIB report 25/2006). The research included consideration of the factors affecting build-up of contamination, and testing the effectiveness of railhead treatment.

245 The focus of the 2006 railhead treatment testing was twofold. It investigated whether the speed of the railhead treatment could be increased to integrate the service more effectively into the passenger service timetables and reduce delays. It also investigated the effects of increasing the pressure of water jetting in removing contamination. The research concluded that it was justifiable to increase the speed of railhead treatment services from 40 mph (64 km/h) to 60 mph (96 km/h) with a recommendation for the water pressure to be increased from 1000 to 1500 bar. At the time of the testing, it was noted that treatment undertaken at 60 mph (96 km/h) would remove around of 85% of the contamination.

246 Despite the testing and research, the relationship between environmental factors, track usage, and the rate of build-up of contamination affecting railhead adhesion is not well understood. Furthermore, RAIB found no evidence that the understanding of the longevity of the benefits from a given railhead treatment regime was clearly understood. Limited further research has been undertaken on this subject since the 2006 testing. Witness evidence suggests that the rail industry's understanding of the limitations and benefits of such regimes has not progressed significantly since that date.

247 This means that there is uncertainty associated with predicting where very low adhesion will occur. This uncertainty makes the sharing of information between train operators and Network Rail critical to managing the risks associated with low adhesion, especially during the autumn leaf fall season.

248 The lack of clear guidance on how long a railhead treatment remains effective has led to standard treatment patterns being used. Network Rail's Wessex route applies a regime of two railhead treatment runs each weekday, and one per day at weekends. However, there appears to be little scientific justification for this pattern. The SDS did not consult others, such as Network Rail's Technical Authority, when determining it and witness evidence shows there was a lack of understanding within Wessex route as to whether the aspiration at weekends was for one run each calendar day or a maximum interval between treatment runs of 24 hours (paragraph 102).

249 Witness and documentary evidence also shows the planned treatment at weekends was frequently delayed or cancelled in Network Rail's Wessex route without any assessment of the risk, or alternative mitigations being implemented. This was the case for the MPV treatment on 31 October, despite the poor weather forecast for the weekend being received on 29 October. This unmitigated delay had become the accepted practice and provides further evidence of a lack of understanding of how effective railhead treatment was at controlling low adhesion risk.

Weather response standards

250 Network Rail standards NR/L3/OPS/045/3.1T7, 'Weather Arrangements' (issue 3, June 2020) and NR/L3/OPS/021/01 outline the actions to be taken following receipt of a weather warning. The forecast for 31 October correctly predicted a high risk of leaf fall and a 'red' (poor adhesion) day (paragraph 168). However, neither of these two standards requires, or provides guidance for route control or the SDS to assess the possible impact of the weather forecasts on the risk of low railhead adhesion. In essence, there is nothing to drive consideration of any necessary additional control measures for low adhesion in Network Rail weather response standards.

251 This meant that, even though the weather forecast on 29 October highlighted an 'adverse' weather warning and a red day for low adhesion, no additional risk assessment was undertaken. If such an assessment had been undertaken, it might have highlighted the significance of the delayed MPV run and additional mitigation might have been considered (paragraph 160).

252 The weather forecast for 31 October 2021 did not trigger an EWAT (paragraph 94). The process for instigating an EWAT does not consider how the weather conditions during the day could affect the risk of low adhesion. This meant that there was no recognition by the WICC of the need to consider the consequences of the delayed MPV railhead treatment run or to consider additional mitigation, such as a GSM-R message to warn train drivers (see paragraph 326).

Competence management

Seasons delivery specialist (SDS)

253 In order to effectively implement the requirements of Network Rail standards such as NR/L2/OPS/095, staff undertaking the role of SDS require an appropriate level of training and competence. However, RAIB found that there was no formal competence development framework for the SDS role, that training was effectively on-the-job in nature and that the Wessex route SDS in post at the time of the accident was primarily relying on the working arrangements set up by their predecessor.

254 The Wessex route SDS in post at the time of the accident entered the role in early 2020, having joined Network Rail on the graduate entry scheme in 2019 (paragraph 25). On taking up the position, the SDS completed a one-day e-learning course and was provided with a short period of mentoring support from a seasonal specialist in Network Rail's Technical Authority.

255 Witness evidence shows that this lack of a formal framework apparently led to gaps in the breadth and depth in the professional knowledge of this and other SDSs. For example, the Wessex route SDS at the time of the accident was confused as to which risk assessment model should be used to drive the action plan for autumn preparedness. RAIB also found that none of the Wessex route SDSs in post from 2014 to 2021 were aware of Network Rail's signal overrun risk assessment process, possibly affecting their appreciation of how low adhesion affects the risk of SPADs. The lack of formal training in technical and non-technical skills also meant that the SDS at the time of the accident neither appreciated the importance of, nor had the confidence to engage in, co-ordination activities with other departments (paragraph 231).

256 Witness evidence indicates that the role of the SDS has primarily been seen as a short-term secondment filled by a graduate, as a 'stepping-stone' to gain experience over a wide range of disciplines. This may explain the lack of a formal training framework and suggests that the importance of the SDS role was not fully recognised within Network Rail.

257 An internal audit of Network Rail's Western route in September 2019 (paragraph 113) identified the need to improve the competency and training requirements for the role of SDS. In particular, the audit report noted that the e-learning did not capture the wide range of knowledge in seasonal risks, hazards and mitigations required for the role. Although witnesses stated that this report would have been shared with Network Rail's Wessex route, neither the SDS nor their manager was aware of it. This meant that none of the report's recommendations were considered or applied in Network Rail's Wessex route.

258 Witness evidence is that the title of 'specialist' also affected how other members of staff interacted with the SDS. In some circumstances, staff were not willing to challenge the SDS as they believed them to be the expert in that field. However, the SDS did not regard themself as an expert in these terms.

Off track staff

259 Network Rail's vegetation management standard NR/L2/OTK/5201 (paragraph 136) requires that relevant assessment staff have the correct skills and knowledge to understand what they are inspecting. During 2018 and 2019 Network Rail updated this standard. These revisions and the associated training (paragraph 141) were supposed to help facilitate MDU off track staff to undertake the leaf fall risk assessments.

260 However, witness evidence suggests that off track staff did not feel that they had been given sufficient training in leaf fall risk assessment and that they did not fully understand when or how to apply the revised standard. Training consisted of a one-day e-learning course, covering leaf fall assessment and how to identify levels of railhead contamination. Furthermore, staff did not have the underlying arboriculture knowledge to undertake the assessments or to understand the consequences of leaf fall on low adhesion risk. Consequently, the MDU off track section manager refused to allow their staff to undertake leaf fall assessments until adequate training had been provided.

261 The internal level 2 audit of the Wessex outer MDU in 2021 (paragraph 112) noted a good practice item associated with the off track section manager's understanding of their team's competence, as well as the need for new staff to shadow others and to be mentored. Although the auditor identified the lack of tree and leaf fall management plans, they classed these only as observations. As such these were not tracked and no action was taken before the accident to resolve them. Furthermore, the auditor did not identify that the lack of tree and leaf fall strategies stemmed from the gap in the competence of staff to undertake leaf fall risk assessments.

262 In 2020, ORR identified deficiencies in the training and competence of off track staff undertaking this type of work (see paragraph 305). ORR's recommended actions had not been carried out by the time of the accident on 31 October 2021. Despite this, witness evidence indicates that Network Rail had nevertheless identified the issue and was developing a training and competency framework for off track staff at that time.

South Western Railway's arrangements for dealing with low adhesion

263 **South Western Railway had not effectively prepared its drivers for assessing and reporting low adhesion conditions. This is a possible underlying factor.**

264 SWR Operations Manual (AP21, issue 1) includes an outline of the implementation of arrangements to minimise the risk to safe operation of trains during the autumn leaf fall period. Specifically SWR's professional driving policy (PDP)[29] Section 15 'Autumn' requires drivers to *'drive defensively according to the prevailing conditions, braking capabilities of the traction driven, utilising WSP sanding and being proactive to the available advice regarding adhesion information/forecasts'.* The policy also requires drivers to be aware how stock formation can impact on stopping distances and advises that *'shorter formations have a higher risk of sliding so often requires a greater stopping distance'.*

265 In addition, the PDP also requires that drivers '*must also be aware of identified low rail adhesion locations on the routes you sign, adjusting the driving technique accordingly. These locations are listed in the SWR Route Maps and identified by trackside signage'* (although the signage was missing, paragraph 158).

266 The SWR Autumn train driver brief (2021) provided guidance, as per the Rule Book (see paragraph 272), on the levels of rail adhesion and their classification as *'good'*, *'expected'* and *'reportable'*. The brief required a driver encountering low adhesion to inform the signaller immediately, provided the conditions were worse than expected for the location and environment. Witness and OTDR evidence shows that several train drivers during the day had encountered varying degrees of low wheel/rail adhesion. However, none of these drivers had formally reported the presence of low adhesion to the signaller and RAIB has no evidence to confirm whether the level of adhesion should have been considered as 'reportable'.

267 It is also possible that an opportunity was missed earlier in the day to identify railhead contamination as the cause of low adhesion in the area, when train 1L13 collided with the tree just beyond Broken Cross bridge (paragraph 47). During their conversation reporting the incident to the signaller, the driver stated that the train's braking was affected by "slipping", but they did not identify railhead contamination as a factor. The signaller did not enquire further as to whether the driver considered the low adhesion conditions to be a cause of the 'slipping' or if the low adhesion should be classified as reportable, and no further action was taken.

268 The knowledge required by drivers to identify and deal with low adhesion should be obtained through training and briefings based on SWR's professional driving policy and autumn briefing, which is given to all drivers. New, post qualified and drivers who had been involved in a low adhesion incident in the previous 12 months are required to have training in addition to the annual autumn briefings. This requirement did not apply to experienced drivers. In line with the policy, all SWR train drivers are expected to make themselves aware of weather forecasts and adhesion conditions through reading notices placed at the booking-on points (paragraph 96). The autumn briefing is produced each year by SWR and is based on its own autumn strategy and Network Rail's Wessex route autumn working arrangements document.

[29] South Western Railway Professional driving Policy version 1.0 issued August 2021 and Autumn brief for drivers and guards (reference SB003-2021) issued 08/10/21.

269 The 2021 autumn briefing included guidance on reporting low adhesion, levels of contamination and details of known HRLA sites. The briefing generally focused on reactive measures for drivers experiencing low adhesion and only provided limited guidance on proactively detecting it. The briefing also contained less information than in previous years, and some topics such as carrying out frequent running brake tests to test railhead adhesion levels were omitted altogether.

270 Data provided by Network Rail shows that, from 2018 to November 2021, there had been an ongoing reduction in the number of reports of low adhesion from drivers to signallers in Network Rail's Wessex route.

271 From 2018 to 2020, SWR autumn briefings took place face-to-face in groups. However, in early 2021 SWR Driver Operations decided to make use of the available technology and introduce an electronic briefing process. As such, in September 2021, the autumn briefing was published on the company's intranet, with notices posted at drivers' booking-on points that the briefing was available; drivers could request a hard copy. This meant there was no immediate opportunity for drivers to ask questions[30] or for SWR managers to emphasise critical learning. Train drivers could still seek clarification from their managers by email or when the opportunity arose.

272 Section 28 of Rule Book Module TW1 requires that drivers report certain levels of low railhead adhesion to the signaller. Before 2018, low adhesion had been classified as either '*low*' or '*exceptionally poor*', depending on where a driver experienced difficulties in stopping or starting. Both '*low*' and '*exceptionally poor*' adhesion were required to be reported to the signaller. This classification was changed in 2018 to three categories, with drivers only required to report the '*reportable*' conditions (paragraph 108). This was defined as '*Railhead adhesion is worse than would be expected for the location and environmental conditions*'. While both sets of requirements need a subjective judgement to be made, the newer requirements are more limiting in terms of what would be considered reportable.

273 Evidence suggests that this change created confusion among many drivers over the correct terminology and reporting criteria. SWR driver managers identified this confusion in 2020 and introduced a reminder to drivers that '**T**rack **I**s **G**ood, **E**xpected or **R**eportable' (TIGER) within the autumn training programme. It is nevertheless possible that this confusion may have persisted and contributed to drivers not reporting conditions on the day to the signaller, particularly with the need for subjective judgement.

274 During autumn 2021, SWR's driver managers installed flip charts at booking-on points as an informal means for drivers to communicate to each other any adhesion issues during their journeys (figure 44). Witness evidence shows that some drivers did not consult the flip charts, either because they did not book on for duty at the booking-on point or because they believed they were out of date by the time they read them. Some drivers were under the impression that reporting low adhesion on the flip chart meant that they were not required to formally report it to the signaller.

[30] If the briefing had been face-to-face, drivers may also have reported that there was no on-track signage to identify the HRLA sites shown within the autumn briefing.

275 RAIB has concluded that the general reduction in reporting of low adhesion was likely to have been a result of a combination of SWR's briefings to drivers, changes in and confusion over reporting requirements and the introduction of the flip charts. There may also have been some effect due to the changes in rail services seen in Autumn 2020 due to the pandemic. Similarly, if drivers had experienced 'reportable' levels of adhesion on the day of the accident, some of these factors may have contributed to them not making any formal ROLAs to the signaller. If there had been a ROLA that day, the signaller would have been required to broadcast GSM-R messages to all drivers warning them of the conditions, and this might have altered the risk perception of the driver of train 1L53 and caused him to start braking earlier on approach to signal SY31.

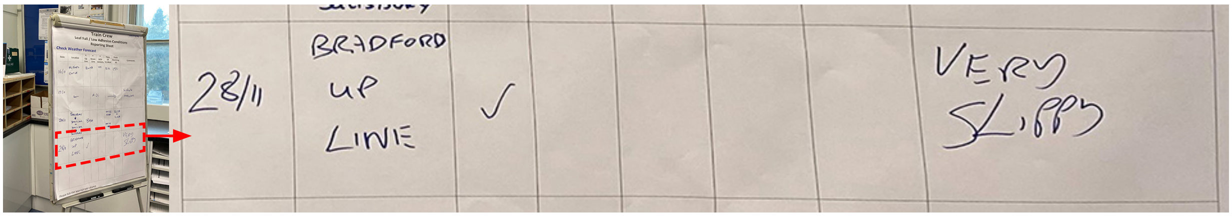

Figure 44: Flip chart (dated 28 November 2021) used by drivers at Salisbury depot to report low adhesion conditions and other safety issues.

Observations

Network Rail TPWS design criteria

276 The TPWS installation at signal SY31 was not compliant with Network Rail requirements for new signalling design.

277 Design of a TPWS installation was governed by Network Rail standard RT/E/S/10138, 'Train Protection and Warning System (TPWS) Transmitter Loop Requirements and Positioning' (issue 3, April 2004). To be effective in controlling the risk of an overrunning train, the designer of a TPWS installation must consider the likely speed of an approaching train. The above standard required that, where there was a reduction in the permissible speed on the approach to the signal being assessed it had to have occurred more than 450 metres on the approach to the TPWS installation for it to be considered in the design. However, technical instruction, TI022 'Provision of TPWS at signals' (issue 4, April 2019) extended this distance to 800 metres. Incorporating a higher approach speed in the TPWS design calculations improves the effectiveness of TPWS in preventing collisions involving trains travelling at the higher speed. However, Network Rail did not make it necessary to apply TI022 retrospectively to existing TPWS installations such as that at Salisbury Tunnel Junction, where the 90 to 50 mph (145 to 80 km/h) permissible speed reduction occurred approximately 500 metres on approach to signal SY31 (figure 5).

278 To retrospectively apply TI022 to the TPWS installation at Salisbury Tunnel Junction would likely require changes to signals SY31, SY29 and SY29R. This might include changes to the signal location, the controls applied to the signals, or a combination of both, so it is not certain what effect adopting the higher approach speed would have on the TPWS design at signal SY31, or on the circumstances of this accident. However, it is probable that the required changes to the signalling would have also reduced the unevenness of signal spacing between signals SY29R, SY29 and SY31 (paragraph 186).

Network Rail's overrun risk assessments

279 **Network Rail's processes for standard signal overrun risk assessment do not require HRLA sites to be accounted for, nor does the identification of a new HRLA site trigger a reassessment of signal overrun risk.**

280 Network Rail quantifies the risk of a train passing a stop signal in accordance with standard NR/L2/SIG/14201/Mod04, '*Signalling Risk Assessment Handbook: Prevention and Mitigation of Overruns – Signal Overrun Risk Assessment Tool Specification*' (issue 3, December 2020). This requires a 'standard' assessment to be undertaken using the Signal Overrun Risk Assessment Tool (SORAT). SORAT is a software tool which takes account of the railway layout and timetable to quantitatively assess hazards and potential conflicts. It produces a risk score for each assessed signal on the rising scale from M4 (lowest risk) to A1 (highest risk). Signal SY31 was assessed on 12 May 2018 and returned a risk score of 'I2'.

281 The standard SORAT assessment assumes a good level of adhesion when calculating overrun risk, using a generic multiplier to quantify the additional risk presented by autumn adhesion conditions. This multiplier is applied to all assessed signals and no account is taken of site-specific contamination or low adhesion issues such as the presence of HRLA sites.

282 The signalling risk assessment handbook requires all signals to be reassessed using SORAT every five years to capture incremental changes. A SORAT assessment can also be triggered by changes including altered permissible speeds, multiple signals passed at danger incidents, accidents, timetable changes or a new or modified track layout. When the accident occurred, signal SY31 had not yet reached the five-year review following its last assessment, nor had any infrastructure change occurred since then which would have required reassessment.

283 Where a standard SORAT assessment determines the signal to have a risk score that is above a set threshold, the process requires that signal to be further assessed in a workshop environment. This process, known as variSPAD, allows the workshop to consider a wider range of hazards and potential mitigations. Those present are prompted by a list of questions/prompts posed by the assessment proforma.

284 Hazards assessed in a variSPAD include whether the signal approach includes irregular signal spacing, significantly greater than necessary braking distance, falling gradients and known areas of low adhesion. All these issues were present on the approach to Salisbury Tunnel Junction. However, because the risk score given to signal SY31 did not reach the required threshold, it was not subject to a variSPAD workshop. This means that, even if the potential presence of an HRLA site had been identified it would not have formed part of the overrun risk assessment for signal SY31.

Factors affecting the severity of consequences

The driver's cab of train 1L53

285 **There was a loss of survival space in the driver's cab of train 1L53.**

286 The initial impact between the two trains was between the front left corner of the driver's cab of train 1L53 and a point around the leading right-hand side passenger doors of the fourth carriage of train 1F30 (paragraph 69). The driver's cab of train 1L53 suffered a loss of survival space[31] that was likely to have led to serious or fatal injuries to the driver, had he not vacated his seat just before impact (paragraph 68). Examination of the surviving parts of the cab structure from the leading carriage (57802) of train 1L53 showed that the front left cab corner pillar became overloaded and failed (figure 45). This pillar would have carried much of the force resulting from the collision.

Figure 45: Cab of train 1L53 (additional damage was caused by the fire and rescue service during the extraction of the injured train driver).

[31] The volume of the carriage body containing the occupants that is to be maintained during a collision to protect the occupants and limit the likelihood of injuries.

287 The design of the class 158 DMU structure (from which the class 159 involved in the accident was derived) was based on UIC 566 ‘Loading of coach bodies and their components’ which was applicable at the time of construction. UIC 566 defined a range of proof loading requirements to apply on the structure when considering its structural integrity. This included longitudinal loads applied to the cab structure at various heights from floor to cantrail, where the bodyside meets the roof, which had to be sustained without permanent deformation. A review of the corresponding requirements contained in the current standard, BS EN 12663-1:2010 ‘Structural requirements of railway vehicle bodies’, shows that the magnitude of the longitudinal loads applied to the cab structure are the same. This suggests that the proof strength of the cab structure of a modern cab would be similar to the proof strength of a class 158 cab structure.

288 Unlike modern standards, such as BS EN 15227 ‘Crashworthiness requirements for rail vehicles’, UIC 566 did not define specific collision scenarios to assess the crashworthiness performance of the carriage in the event of an accident, that is, what happens to the body structure when subjected to loads greater than its proof strength. As such, the class 158 body structure was not designed to meet any specific crashworthiness requirements.

289 Nevertheless, as the class 158 body structure was an early application of welded aluminium to UK train construction, a considerable amount of work was undertaken at that time to understand its crashworthiness performance. Part of this work included assessing its crashworthiness performance against an emerging internal British Railways Board standard, CP-DDE-116 ‘Structural requirements for the bodies of multiple unit vehicles’, which contained collision scenarios. A British Rail report published in 1989 (TR-VST-004) concluded that, when assessed against CP-DDE-116 requirements, ‘*the class 158 is not a good crashworthy structure: high force levels and low energy absorption at low impact velocities are evident with deceleration levels approximately twice the suggested values*’. In 1991, the class 158 cab structure was crush tested in a controlled environment. British Rail report RR-VST-002 concluded that ‘*the energy absorbed by the cab ends in the tests was sufficiently high to meet British Rail’s latest standard but the peak forces generated during the test were much higher than in comparable steel vehicles and the mode of deformation rather aggressive*’.

290 As the proof strength of a class 158 cab structure is likely to be similar to a modern equivalent, RAIB has not made a specific recommendation relating to the driver’s cab of the class 158. The more general question on the crashworthiness performance of traction and rolling stock which predates modern crashworthiness requirements was identified in recommendation 19 of the RAIB investigation into the accident at Carmont, Scotland (see paragraph 326).

Internal sliding vestibule doors

291 **Damage to the internal sliding doors on the train obstructed evacuation routes and prevented train crew from accessing carriages to assist passengers.**

292 Class 158 and class 159 trains have their exterior doors located at each end of the body. The area adjacent to these doors, commonly referred to as the vestibule, is separated from the main saloon area by ‘bi-parting’ sliding doors. The purpose of these doors is to improve passenger comfort, by isolating the saloon area from draughts when the exterior doors are opened.

293 Each saloon to vestibule door has two door leaves (figures 46 and 47). These meet in the middle of the doorway and are power operated such that each leaf opens to its respective side. The vestibule doors are electrically operated, and each leaf moves on runners located above the door aperture.

Figure 46: Image showing jammed vestibule door of the leading carriage of train 1L53.

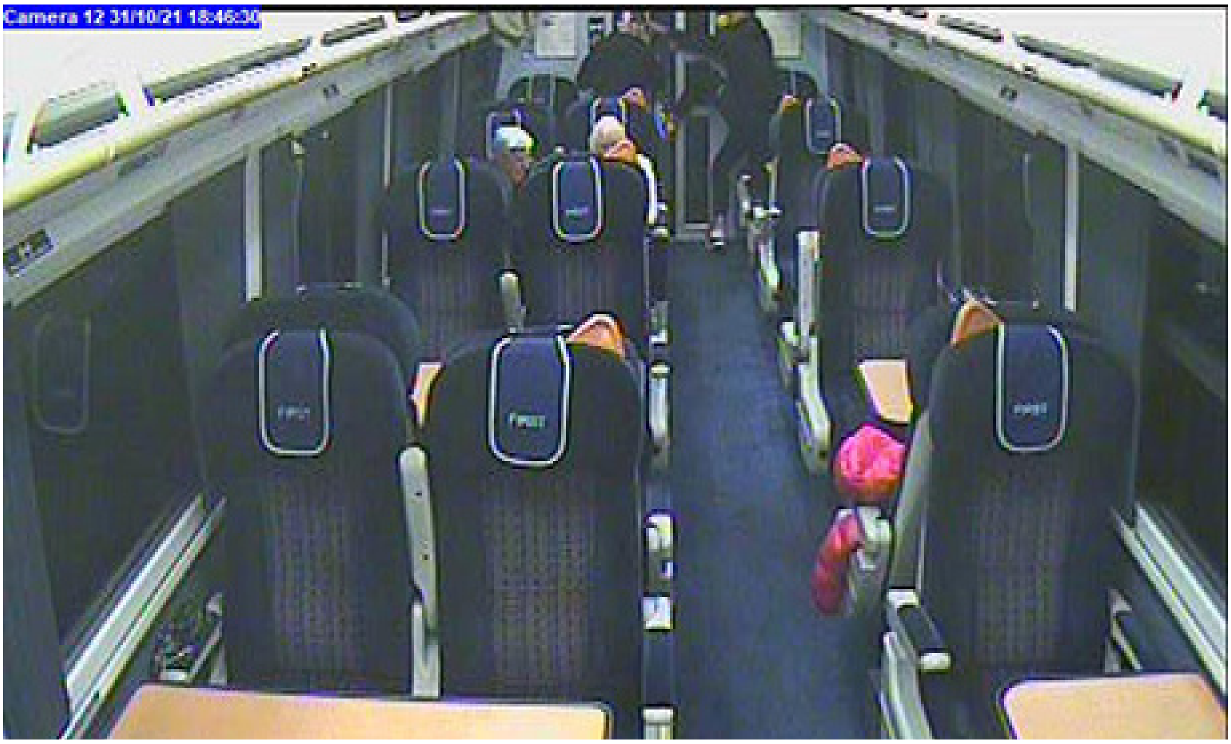

Figure 47: Internal CCTV image showing passengers trying to prise vestibule door open in the rear carriage of train 1L53.

294 Analysis of CCTV footage recovered from the carriages and interviews with witnesses identified that, in the immediate aftermath of the accident, at least three of these doors were unavailable to passengers. These were:

- The leading vestibule door of carriage 57803, the leading carriage of train 1L53.[32] This area of the train, adjacent to the cab, suffered severe damage during the collision. The damage to this door did not obstruct a viable egress route. The significant damage to the leading end of carriage 57803 meant that the exterior doors at that end of the carriage were unusable. In the immediate aftermath of the accident, the trailing vestibule door of 57803 was operable, although this door was subsequently found in a jammed condition (see paragraph 296).
- The trailing door of carriage 52803, the rearmost carriage of train 1L53. CCTV images show passengers forcing this door open and that this clearly required considerable physical effort. If these passengers had been unable to open this door, then the guard of the train would have been unable to move into the train from the vestibule/rear cab area, where they were immediately before the accident, to offer assistance to passengers. This would have also obstructed a viable egress route.
- The leading vestibule door of carriage 52763, the fourth and last carriage of train 1F30. This prevented the guard of this train (who was in the third carriage of train 1F30 at the time of the accident) gaining access to this carriage in the aftermath of the collision. It also meant that passengers who were in the third carriage of this train had only one viable egress route available to them, which was through the cab-end door of the carriage and thence via Fisherton Tunnel to Salisbury station.

295 Although no injuries occurred because of these doors becoming jammed, the carriages were in a tunnel and some diesel fuel had been spilled. Blockage of otherwise viable egress routes is therefore evidently undesirable and may result in passengers panicking and/or injuring themselves when seeking alternative routes as part of an uncontrolled evacuation.

296 Examination of the carriages after recovery found two further jammed vestibule sliding doors. They were the trailing door of carriage 57803, leading carriage of train 1F30, and the trailing door of carriage 57763, the third carriage of train 1F30. There is no evidence to indicate when these doors became jammed, either during the accident or afterwards in the recovery of the carriages.

297 Railway Industry Standard RIS-2730-RST[33] sets out requirements for railway vehicle fire safety and evacuation. This standard states that internal sliding doors shall:

a) *Slide open in opposing directions at each end of the passenger saloon; or*

b) *Be bi-parting; or*

[32] The leading vestibules on Class 159 trains are normally inaccessible to passengers. However, a release is available to allow access in an emergency. The release for the leading vestibule door of 57803 had not been operated.

[33] RIS-2730-RST issue 1.1 dated September 2021 is the current issue, although this standard and predecessors have existed for many years, with requirements being substantially unchanged.

c) *Be fitted with a means of escape within the door opening which allows through egress in the event of the door becoming jammed, so as to comply with clause 4.3.2.1 (e) of BS EN 45545-4:2013.*

298 The bi-parting doors fitted to class 158 and class 159 trains comply with clause 'b' of this standard. It is evident that the doors became jammed due to them derailing from their runners. However, RAIB has not investigated the specific mechanism/s that caused them to derail. Nor has it considered whether similar doors are fitted to carriages beyond the class 158/159 fleets.

The role of the safety authority

299 The Office of Rail and Road (ORR) regulates the railway industry's health and safety performance. Its role includes the monitoring of health and safety performance, carrying out assessments and taking action to enforce compliance with health and safety law. ORR is also tasked with ensuring that appropriate action is taken in response to RAIB recommendations.

300 ORR plans its routine inspection work on the basis of strategic risk priorities and its analysis of where it can secure the most significant improvements in safety management. Its inspections and assessments aim to draw systemic conclusions which will promote improved safety arrangements across a wide range of activities, rather than identifying specific shortcomings. However, if any shortcomings were to be identified during inspections and assessments, then these would be raised by ORR with the duty holder concerned.

301 ORR reported to RAIB that it has been challenging Network Rail regarding its management of vegetation since 2014. This included the monitoring of the company's performance across its regions and routes.

302 In 2017, ORR escalated this challenge and required all routes within Network Rail to develop and implement long-term plans and interim mitigation measures to manage vegetation risks. Each route demonstrated to ORR that plans were in place and were being implemented. Network Rail's Wessex route submitted a 15-year plan to bring the route back to compliance with Network Rail's standard by 2034. ORR therefore moved Network Rail onto a routine monitoring plan regarding its management of vegetation risks in early 2020.

303 During this routine monitoring, ORR identified declining performance in the management of vegetation within Network Rail's Southern region, which includes Wessex route. This triggered an ORR targeted review of the route's performance at the start of financial year 2021 to 2022.

304 ORR's assessment of Network Rail's Southern region was that there were varying levels of maturity of vegetation management across the routes forming the region, namely, Wessex, Kent and Sussex. While all three of these routes recognised the ongoing risks from a lack of vegetation management, no evidence was found of any immediate risks to safety. However, ORR was particularly concerned that Network Rail's Wessex route was not able to provide sufficient evidence on how it effectively resourced, prioritised and delivered works against plans to control vegetation risks.

305 ORR's review indicated significant vulnerabilities with risk controls in the following areas:

(a) Communication, co-ordination, and liaison between disciplines (such as operations, off track and track) responsible for vegetation management, which could result in risks being unmanaged.

(b) The training and competence framework for lineside staff, and the lack of senior management accountability for lineside, in particular, issues related to tree assessment and vegetation management, had the potential for risks to go unrecognised.

306 This led to ORR's decision in July 2021 to consider vegetation management within Network Rail's Southern region, including Wessex route, as an emerging issue, with the potential for further escalation. ORR provided a corresponding assessment of the route's vegetation management performance as part of its 2021 to 2022 Network Rail Annual Assessment.[34]

307 By the end of October 2021, ORR considered that Network Rail had made insufficient progress in addressing senior leadership for lineside management and committing to the delivery of additional vegetation management works to manage high risk leaf fall sites. This resulted in ORR escalating this topic with Network Rail with further engagement and monitoring.[35] After the accident, in December 2021 ORR took further action in response to evidence of the emerging themes from the Salisbury accident (see paragraph 356).

[34] Annual Assessment of Network Rail - April 2021 to March 2022, 20 July 2022 (www.orr.gov.uk).

[35] In June 2022, ORR considered Network Rail's Southern region had made sufficient progress to return to routine monitoring.

Previous occurrences of a similar character

Autumn Adhesion Investigation

Part 1: Esher, 25 November 2005

308 On 25 November 2005, a South West Trains (the predecessor train operating company to SWR) service from Alton to Waterloo passed signals at danger on the Up Fast line between Esher and Hampton Court Junction by approximately 200 metres. After passing the signal, the train came within 200 metres of another service from Woking to Waterloo, which had crossed from the Up Slow to the Up Fast line at Hampton Court Junction.

309 The investigation into the incident (RAIB report 25/2006 (Part 1)) was undertaken in parallel with the investigation into the SPAD that occurred at Lewes on 30 November 2005 and a general investigation into the causes of adhesion-related station overrun and SPAD incidents during Autumn 2005. RAIB made three recommendations in this report which were not directly linked to the causes of the Salisbury accident.

Part 2: Lewes, 30 November 2005

310 On 30 November 2005, a train passed a signal located at the end of platform 3 at Lewes station at danger. After passing the signal at danger, the train ran through a set of points which were not set for the passage of the train. Another train that had departed from platform 5 at Lewes station on time was approaching the points when the driver heard the other train approaching and, realising that the two trains were on a conflicting route, stopped some 30 metres from the point of conflict. RAIB's investigation report (RAIB report 25/2006 (Part 2)) made three recommendations which were not directly relevant to the causes of the Salisbury accident.

Part 3: Review of adhesion-related incidents in Autumn 2005

311 Part 3 of RAIB's review (RAIB report 25/2006 (Part 3)) found that the immediate cause of the SPAD incidents at Esher and Lewes was poor adhesion between wheel and rail. The two incidents occurred against a backdrop of an increase in the number of adhesion-related SPAD incidents and a significant increase in the number of adhesion-related station overrun incidents on the national rail network during autumn 2005 compared with autumn 2004. The purpose of the class investigation was to establish the causes of this increase and any common themes. A number of recommendations were made as a result of the class investigation.

312 Short-term recommendations related to the following:

- sanding systems
- monitoring of the level of sand
- defensive driving techniques
- vegetation management on approaches to junctions
- undertaking low adhesion railhead treatment
- proposing research into technology to estimate levels of contamination and/or adhesion.

313 Longer-term recommendations related to the following:

- research to determine how long low adhesion endures
- possible methods for identifying the presence of low adhesion
- methods for preventing railhead contamination formation and dispersal
- fitment of automatic sanding equipment
- braking performance of trains
- WSP equipment and modelling techniques
- research to determine whether magnetic track brakes were a cost-effective solution for new-build rolling stock and/or retrofitting to existing rolling stock
- how information and intelligence and use of wireless remote data transmission from rolling stock can help in providing details of low adhesion conditions in real time.

314 By 2014, ORR considered that sufficient action had been taken against all 19 recommendations for them to be considered as implemented. RAIB has stated in its annual reports that it had concerns that the actions taken, or proposed, to address six of these recommendations were inappropriate or insufficient to address the risks identified.

Passenger train collision at Darlington, 3 October 2009

315 On 3 October 2009, a passenger train arriving at Darlington station collided with the rear of another passenger train which had just started to depart from the same platform. The collision caused a small number of minor injuries, and two passengers were taken to hospital for treatment. Both trains suffered minor damage. The primary cause of the accident was contamination of the railhead at the south end of the station, with high levels of leaf/vegetation material being found.

316 RAIB's safety bulletin on this accident (RAIB bulletin 01/2010) found that it was likely that the poor weather and high winds resulted in leaves and other vegetation being blown onto the line, from where they could be picked up by the wheels of passing trains and transported short distances. This material, having been deposited from trees during the early part of autumn, is likely to have had a high moisture content, which would have significantly affected the existing low level of adhesion. Bulletins had a similar role to RAIB's current safety digests and did not include recommendations.

Norwich Road level crossing, New Rackheath, Norfolk, 24 November 2019

317 On 24 November 2019, the barriers at Norwich Road level crossing, near New Rackheath, Norfolk, lifted as a passenger train from Norwich to Sheringham was approaching (RAIB report 15/2020). Two road vehicles crossed the railway in front of the train, which reached the crossing less than half a second after the second road vehicle was clear. The investigation found that leaf fall and atmospheric conditions had resulted in contamination of the railhead and low adhesion conditions. The contamination had not been removed because there were no railhead treatment trains on the Norwich to Sheringham line at weekends. The incident involved new rolling stock running on a different band on the railhead to the previous trains and as such the contamination had not been cleared resulting in poor electrical contact.

318 As a result of the recommendations made by RAIB, Network Rail reported it had made an emergency change and modified its approach to autumn management, specifically regarding the items to consider when planning the use of railhead treatment trains as part of its national operating standard NR/L3/OPS/045. This instruction was sent to the seasonal delivery managers and SDSs and required them to liaise with train operators through the joint season management group to identify any changes in rolling stock. ORR has determined that these recommendations have been implemented.

Train collision with fallen tree and derailment near Balderton, Cheshire, 26 November 2021

319 On 26 November 2021, an empty passenger train collided with part of a fallen tree while travelling at 46 mph (74 km/h) and derailed (RAIB safety digest 03/2022). The train was a class 150 DMU travelling between Wrexham General and Chester. There were no injuries, but minor damage was caused to the train and to local signalling equipment. The tree was felled by poor weather. The Meteorological Office report about Storm Arwen stated that trees, including large mature trees, were felled across the north of the UK due to the unusual direction of the wind.

320 The safety digest highlighted the recommendations made to Network Rail in RAIB's Carmont report (RAIB report 02/2022) (see paragraph 326) to address some of the factors present in the Balderton accident. These related to improving processes for mitigating the effects of extreme weather conditions and enhancing route control staff skills and resources to improve incident management. Additionally, RSSB started a project to assess the effectiveness of blanket speed restrictions in mitigating risks from trains colliding with trees or landslips.[36]

[36] 'Effectiveness of blanket speed restrictions in managing and mitigating risks from trains running into trees or landslips', available at https://www.rssb.co.uk/research-catalogue/CatalogueItem/T1252.

Summary of conclusions

Immediate cause

321 Train 1L53 passed signal SY31 at danger and could not stop before colliding with train 1F30 (paragraph 114).

Causal factors

322 The causal factors were:

a. Wheel/rail adhesion was very low in the area where the driver of train 1L53 applied the train's brakes. This causal factor arose due to a combination of the following:

   i. The railhead was contaminated with fallen leaf debris, much of it as a result of the weather conditions since the last railhead treatment run, coupled with an increased density of vegetation; and wet conditions from the band of drizzle that had recently passed over (paragraph 123, **Recommendations 1, 2 and 3**).

   ii. Network Rail's Wessex route had not effectively mitigated the railhead contamination (paragraph 156, **Recommendations 1, 2, 4, and 5**).

b. The driver did not apply train 1L53's brakes sufficiently early on approach to protecting signal SY31 to avoid running onto the junction, given the prevailing levels of wheel/rail adhesion (paragraph 172, **Recommendation 8**).

c. The braking systems of train 1L53 were unable to mitigate the effects of the prevailing wheel/rail adhesion conditions (paragraph 203, **Recommendation 9**).

Underlying factors

323 The underlying factors were:

a. Network Rail's Wessex route did not effectively manage the risks of low adhesion associated with the leaf fall season. This is a probable underlying factor and included issues relating to:

   i. resourcing (paragraph 225, **Recommendations 2 and 3**)

   ii. liaison between departments (paragraph 231, **Recommendations 1, 2 and 3**)

   iii. track access constraints (paragraph 237, **Recommendation 1**)

   iv. MOM inspection process (paragraph 241, **Recommendation 1**)

   v. understanding of railhead treatment effectiveness (paragraph 243, **Recommendations 1 and 2**)

   vi. weather response standards (paragraph 250, **Recommendations 1, 4 and 5** and Recommendation 7 of RAIB report 02/2022, see paragraph 326)

vii. staff competences (paragraph 253, **Recommendations 2 and 3** see also paragraphs 337 to 342).

b. South Western Railway had not effectively prepared its drivers for assessing and reporting low adhesion conditions. This is a possible underlying factor (paragraph 263, **Recommendation 8**, see also paragraphs 345 to 347).

Additional observations

324 Although not linked to the accident on 31 October 2021, RAIB made the following two observations:

a. The TPWS installation at signal SY31 was not compliant with Network Rail requirements for new signalling design (paragraph 276, **Recommendation 6**).

b. Network Rail's processes for standard signal overrun risk assessment do not require HRLA sites to be accounted for, nor does the identification of a new HRLA site trigger a reassessment of signal overrun risk (paragraph 279, **Recommendation 7**).

325 Factors that affected the consequences were:

a. There was a loss of survival space in the driver's cab of train 1L53 (paragraph 285, no recommendation made as this is covered by Recommendation 19 of RAIB report 02/2022, see paragraph 326).

b. Damage to the internal sliding doors on the train obstructed evacuation routes and prevented train crew from accessing carriages to assist passengers (paragraph 291, **Recommendation 10**).

Previous recommendations that had the potential to address one or more factors identified in this report

Carmont, Aberdeenshire (2020) (published March 2022)

326 On 12 August 2020, a passenger train collided with debris washed from a drain onto the track near Carmont, Aberdeenshire, following very heavy rainfall (RAIB report 02/2022). The passenger train service from Aberdeen to Glasgow was returning towards Aberdeen due to a blockage that had been reported on the line ahead. There were nine people on board, six passengers and three railway employees (one of whom was travelling as a passenger). The train was travelling at 73 mph (117 km/h), just below the normal speed for the line, when the collision occurred. This caused the train to derail and deviate to the left, before striking a bridge parapet which caused the carriages to scatter. Tragically, three people died as a result of the accident.

327 Following the accident, Scotland's Railway established a permanently staffed weather desk position. Network Rail has informed RAIB that suitably qualified people have been recruited to cover this position, which is responsible for monitoring weather conditions and advising controllers on the necessary precautionary actions. In the light of the likelihood that climate change will exacerbate this risk still further, Network Rail also decided to commission two task forces to advise on earthworks management and weather.

328 The RAIB report into the accident at Carmont was published in March 2022, five months after the accident at Salisbury. RAIB made 20 safety recommendations in its report, two of which, recommendations 7 and 19, are relevant to the accident at Salisbury Tunnel Junction. Recommendation 7 reads as follows:

Recommendation 7

This recommendation is intended to enhance the ability of route control staff to contribute to the safe operation of a modern railway by making good safety decisions in difficult circumstances based on a holistic assessment of the most relevant information. It is intended to build on the work already undertaken as part of Network Rail's 21st Century Operations programme.

Network Rail, in conjunction with train operating companies, should review the capability of route control rooms to effectively manage complex, widespread and unusual situations such as abnormal weather conditions and multiple infrastructure failures. This review should consider the steps needed to ensure that route controls have sufficient staff with appropriate skills (technical and non-technical), experience and knowledge, all with clearly defined responsibilities and accountabilities. The review should therefore examine how Network Rail ensures that route control staff are provided with appropriate training, learning and professional development for their roles, supported by means of a comprehensive competence management system, that enables them to feel confident and empowered to make difficult decisions.

As part of this review, Network Rail should also compare its railway control safety-related decision-making frameworks with those in other organisations (such as off-shore exploration and air traffic management) to determine if good practices can be imported into the railway environment.

The review should be used to inform the development of a timebound programme for the implementation of the measures that are needed to develop the incident management capability of route controls.

329 Network Rail reported to ORR that a plan had been implemented setting out various workstreams to address recommendation 7, relating to a training and competence framework for more effective decision-making training for control room staff and to improve understanding of the impact of abnormal weather conditions.

330 Network Rail has also established a working group to review the critical activities in Route and National Operations Control, with the aim of producing a better process for managing assurance. The new process will take account of the ORR guidance document Railway Safety Publication 1 'Developing and Maintaining Staff Competence'.[37] The work is closely linked to the development of a competence framework to identify critical decision-making activities for staff referred to in recommendation 7. The recommendation remains open at the time of this report.

331 The second relevant recommendation, recommendation 19, reads as follows:

Recommendation 19

The intent of this recommendation is to evaluate the additional risk to train occupants associated with the continued operation of HSTs, which entered service before modern crashworthiness standards were introduced in July 1994. This will enable the future planning of HST deployment to be informed by a fuller understanding of any additional risk and the costs and safety benefits of any potential mitigation measures. This learning should also inform thinking about the mitigation of similar risks associated with the operation of other types of main line rolling stock.

Operators of HSTs, in consultation with train owners, ORR, DfT, devolved nations' transport agencies and RSSB should do the following:

a) Assess the additional risk to train occupants associated with the lack of certain modern crashworthiness features compared to trains compliant with Railway Group Standard GM/RT2100 issue 1 (July 1994), also taking account of age-related factors affecting condition (such as corrosion). This assessment should include a review of previous crashworthiness research (including driver safety), a review of previous accidents, consideration of future train accident risk, the findings presented in this report and any relevant engineering assessments.

b) Based on the outcome of a) and cost benefit analysis, identify reasonably practicable measures to control any identified areas of additional risk for HSTs, and develop a risk-based methodology for determining whether, and if so when, HSTs should be modified, redeployed or withdrawn from service.

[37] https://www.orr.gov.uk/media/10885.

c) In consultation with operators of other pre-1994 passenger rolling stock, develop and issue formalised industry guidance for assessing and mitigating the risk associated with the continued operation of HSTs and other types of main line passenger rolling stock designed before the introduction of modern crashworthiness standards in 1994.

332 ORR reported that it had hosted a meeting on 6 April 2022 with owners and operators of class 43 high speed trains (HST), together with government bodies and RSSB, to consider how recommendation 19 should be addressed. The initial consideration of the recommendation by relevant parties was done by the Carmont Recommendation Steering Group (CRSG), co-ordinated by RSSB.

333 After reviewing the information provided by the bodies and organisations responsible for implementing recommendation 19, ORR concluded that, in accordance with the Railways (Accident Investigation and Reporting) Regulations 2005, RSSB has taken the recommendation into consideration and is taking action to implement it. The recommendation remains open at the time of this report.

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

334 Network Rail and SWR jointly undertook an internal rail industry investigation into the accident. The report from this investigation recommended actions for both Network Rail and SWR. Those relevant to RAIB's findings are reported below.

Network Rail

335 The joint industry review placed the following actions on Network Rail:

a. Network Rail's Head of Operations, Principles and Standards to undertake the following:
   - Liaise with RSSB to review rail industry standard RIS/8040/TOM, 'Managing Low Adhesion' (then at issue 1) to include a requirement for the introduction of restrictive working arrangements on the control of trains when poor or exceptional railhead conditions are forecast, and the planned mitigation has not been provided (see also paragraph 350).
   - Review Network Rail standard NR/L2/OPS/095 and the process of risk assessment that is used to identify HRLA sites. The review will consider the consequences of incidents such as SPADs, overruns and derailments arising from low adhesion conditions; this review is still in progress.
   - Review compliance with Section 5 of NR/L3/OPS/021/01 for the installation of trackside signage to indicate an HRLA site across all routes; this review is still in progress.

b. In conjunction with (a), Network Rail's Head of Seasons, Weather and Resilience to review and align the standards relating to how Network Rail manages the risk from low rail adhesion. The work is continuing and is expected to be completed by the end of 2023.

c. Network Rail's Head of Operations, Principles, and Standards to enhance the training of controllers to provide them with the knowledge, skills and competency to manage complex or extreme situations[38] (paragraph 328).

d. Route Operations Directors to review the existing command structure, available resources and support within Network Rail and integrated control centres to assess the effectiveness of staff to deal with significant disruptive events, including low adhesion. Any learning or recommendations is to be included within a plan to address any shortfalls in resources. The work is continuing and is expected to be completed by the end of 2023 (see paragraph 342d).

e. Network Rail's Head of Seasons, Weather and Resilience to arrange for research to be undertaken to better understand the effectiveness of water jetting by the MPV at differing speeds, and from this to review the water jetting criteria of the MPV on Wessex and other routes. This work is ongoing at the time of writing this report (see paragraphs 344d and 345g).

[38] This is a duplication of a recommendation into the train derailment at Carmont.

f. Network Rail Southern region appointed a new regional asset manager for off track and a principal engineer for off track. However, maintenance delivery units on Southern region remain the responsibility of the track maintenance engineer (off track), with two TMEs currently in post in Wessex route and an additional three planned for Kent and Sussex routes.

336 Other actions that Network Rail has reported that it has taken are discussed in the following paragraphs.

Training and competence for staff

337 Network Rail has reviewed its training and competence framework for off track staff and has introduced a new standard, NR/L2/CIV/1000/01 Module 1, 'Competence Management for Drainage and Lineside'. This standard defines a competence management system for off track staff, including a definition of the knowledge, skills and behaviours required and the process for assessment.

338 Network Rail has stated that the assessment framework will:

a. define the knowledge, skills and behaviours of the roles across the drainage and lineside (off track) activities such as inspection, assessment, maintenance, evaluation, design and construction, assurance and management

b. define competences and capabilities to support the development of a career pathway

c. support decisions to minimise the impacts of safety, performance, reputational and environmental risk.

339 Although Network Rail has introduced this new standard, the associated training programme for off track staff remains under development. This training is planned to be introduced in 2024, and so this action is still in progress.

340 Network Rail has also produced a training framework to develop the role of the SDS in technical and non-technical skills. This training is planned to be introduced in late 2023, and so this action is still in progress.

Autumn management

341 Network Rail has reported that it will revise NR/L3/OPS/021/01, 'Autumn Management' (which will be retitled as 'Adhesion Management') to require a risk assessment to be undertaken when planned railhead treatment is not to be carried out. The revision will also require MOM inspection checks of HRLA sites to be undertaken at least weekly and on a forecast 'red' or 'black' adhesion risk leaf fall day.

342 In 2021 Network Rail established a working group to review the factors that had been identified by RAIB and its internal investigation. In August 2023 Network Rail provided an update on these actions:

a. Updates to standards and processes within NR/L2/OPS/021, NR/L3/OPS/021/01 and NR/L3/OPS/045/3.17 are in progress and these changes in conjunction with any learning from the RAIB report will be implemented following the five-yearly review of RIS-3708-TOM in 2023.

b. The title of the autumn working arrangements document, NR/L3/OPS/021/01, has been changed to 'Adhesion Management' to capture the risks outside of autumn (as part of the recommendation 1 from the RAIB Llanharan investigation (RAIB report 03/2023).

c. The SDS and off track e-learning training for adhesion has been enhanced.

d. It is providing training and support to control room and seasons delivery staff with weather academy workshops, building incident scenarios to facilitate the rehearsal of weather plans and responses.

e. It has introduced meteorology training with MetDesk for seasons delivery staff and their managers.

343 Network Rail held its first national low adhesion conference in February 2023, bringing together its SDS community, MetDesk and research/railhead treatment providers to share good practice and research.[39]

Network Rail's Wessex route

344 Network Rail's Wessex route reports that it has taken the following actions as a result of the joint industry investigation:

a. The SAE and the newly appointed region asset manager (off track) are reviewing and clarifying the required responsibilities for delivering leaf fall risk control processes.

b. The route operations risk advisor and route asset manager (signalling) are reviewing the SORAT assessment process for signal SY31 and other signals in close proximity to junctions where sections of HRLA sites are also in the vicinity to identify any learning potential and any recommendations (currently in progress).

c. Ensured vegetation and leaf fall risk assessment data is included within the Ellipse maintenance database.

d. The speed of MPV railhead trains through designated HRLA sections has been reduced to 40 mph (64 km/h) to improve the effectiveness of the railhead treatment. The railhead treatment programme has also been changed so that all of its lines are treated twice a day on both weekdays and weekends, where possible, during the autumn period.

e. Implemented assurance checks on the route to ensure compliance with the '24-hour missed sites' criterion and ensure that when the railhead is not treated for over 24 hours, these sites are identified as a missed site and specified mitigation is provided by the development of site-specific plans.

f. Implemented assurance processes to ensure checks at high risk sites are being undertaken at least weekly and following a red or black leaf fall adhesion risk forecast, and that there is a process to verify that these checks are being completed.

[39] Similar conferences were held in previous years under the title of 'National Autumn Review'.

g. Undertaken a review of the resources for the autumn control desk within the WICC. This will enable them to be more proactive in monitoring and managing emerging risks from incoming data, including real-time weather information and information from the intelligent infrastructure monitoring of high risk WSTCF sites. This can then inform additional mitigations identified in site-specific plans.

h. Installed new lineside low adhesion signage for all HRLA sites, including those previously without any signage, to assist train driver's identification of the sites.

i. Included consideration of timing and repeat periodicity for GSM-R transmissions during the EWAT calls.

j. Network Rail's operations director Wessex, in conjunction with the train operating companies, is reviewing the adequacy of the timetabling of passenger trains at Salisbury Tunnel Junction with the objective of reducing the frequency of trains that approach signal SY31 at red. This review will also consider the appropriateness of the regulating policy at Salisbury Tunnel Junction.

Network Rail and SWR

345 Network Rail's Wessex route and SWR report that they have taken the following actions as a result of the joint industry investigation:

a. Jointly agreed appropriate mitigation measures for the different levels of low adhesion, including consideration of short formation trains. An additional risk matrix was developed for various service disruptions and included consideration of alternative mitigations where railhead treatment MPVs were unable to cover their circuits. This has already been successfully used by SWR to arrange operational mitigations during Autumn 2022.

b. Before Autumn 2022, they jointly updated the annual autumn working arrangements to ensure that all HRLA sites were identified, reassessed, managed and monitored.

c. Jointly reviewing and redeveloping the ROLA forms.

d. In conjunction with a contractor, commenced a trial on SWR's class 158/159 of on-train rail adhesion monitoring cameras to identify levels of contamination. Network Rail has also fitted similar cameras with GPS technology to railhead treatment MPVs for the same purpose. This work is currently ongoing.

e. Before Autumn 2022, introduced bi-weekly seasonal weather meetings with Network Rail which become weekly during the autumn.

f. Developing software to correlate low adhesion forecasts that work with real-time on-train data. This work is currently ongoing.

g. In collaboration with academia, undertaken testing and research into the factors that affect the rate of build-up of all contaminants that affect low adhesion. The trial[40] looked at the effectiveness of current railhead treatment methodology (water treatment and adhesion modifier) and alternative technologies (laser, plasma and cryogenics). Network Rail is also working with industry to develop other potential long-term solutions.

[40] NR/RPT/6365 – The Future Technologies Trial Close Out Report.

SWR

346 The actions that SWR reports that it has taken as a result of the joint industry investigation are discussed in the following paragraphs.

Driver training

347 SWR has implemented the following actions relating to training and briefing of its drivers:

a. Enhanced its guidance for driving in conditions of low adhesion.

b. Reintroduced face-to-face briefing on autumn arrangements to train drivers to ensure that information has been effectively briefed and understood.

c. Enhanced its train driver briefing process to ensure its drivers are familiar with the format of low adhesion signage. It has also revised the information describing the location of HRLA sites to reference it to visual cues, such as signals and bridge numbers, rather than mileages, thereby making it more effective and memorable.

d. The 2022 autumn brief included the requirement to formally report a low adhesion incident to the signaller, if the driver puts any low adhesion information on the flip chart at the depot booking-on point. SWR has also placed stickers on the flip chart to remind drivers of this requirement. The autumn brief also included HRLA locations and risk scores.

e. Introduced the requirement to publish on the SWR intranet, on a weekly basis, a list of sites where low adhesion incidents have occurred during the previous week. This list will also highlight ‘hot spots’ where there have been two or more incidents of low adhesion within 24 hours.

f. In November 2022, issued a traction notice to instruct all train drivers to complete a running brake test on approach to known areas of HRLA as documented in the Autumn brief.

g. Stopped the use of the pre-recorded GSM-R message that referred to reporting ‘exceptional’ railhead conditions on the SWR driver training simulator. The simulator operator will instead make a scripted general broadcast alerting the train driver to ‘reportable’ adhesion conditions.

Other actions

348 SWR has also implemented the following actions:

a. Enhanced its risk assessment process to consider all relevant information, including the use of shorter train formations during periods of disruption caused by industrial action or weather-related issues.

b. Started a review of the WSP sanding system on diesel multiple unit trains to consider the following:

- sand discharge rates and deployment of a sander air flow control modification
- implementing the use of nozzles that better direct sand, thereby improving adhesion.

c. Started a programme to retrofit single variable rate sanders to its class 158 and class 159 fleet during 2023 (see paragraph 355).

d. Consulted with Porterbrook, the owners of the class 158 and 159 units operated by SWR, to review the risk assessment undertaken before fitment of the current WSP system controller. This review will consider:
   - practicable adhesion benefits of the sanders maintained to comply with the sand discharge limits set in the Porterbrook overhaul specification
   - realistic sander air consumption rates
   - the presumed maximum length of low adhesion track that a train might encounter.

e. Updated its Wessex route risk assessment and posted it on the SWR intranet, which will also include all information associated with route knowledge to make it easier for crews and managers to provide regular updates if information is changed.

f. Appointed a route training manager to ensure that all route risk assessments are up to date. The review process requires the documents to be updated following any major change to the infrastructure, serious operational incidents or every five years, whichever comes sooner.

g. Introduced the ‘Notus’ system to assist in advising SWR drivers of WSP activity on Network Rail’s Wessex route. This information is made available on drivers’ tablets and displays a map which highlights HRLA sites and areas where there have been low adhesion reports (defined as wheelslip events over 7 seconds which have been captured on OTDRs in the previous 24 hours or locations where multiple wheelslip events have been recorded).

h. Training has been delivered to both existing and trainee guards in the use of GSM-R. SWR is also undertaking assessments of the competence of guards in making an emergency call via the GSM-R radio system, and is considering providing training to assist guards in making these calls in emergency situations.

i. Purchased the GSM-R training app that staff can access on their mobile devices at any time to refresh their knowledge.

j. Approached RSSB and the Adhesion Research Group regarding the following (this work is still in progress):
   - proposing research into the development and potential use of on-train technology to detect and automate the process of reporting locations where the adhesion is lower than expected
   - proposing a review of the current Rule Book section on the reporting terminology for low or poor railhead adhesion
   - proposing a review of the suitability of the braking instructions recommended in the independent report produced by the Adhesion Working Group in April 2006 on braking in adverse rail conditions, and the instructions to a driver when a forecast has identified a ‘Red’ or ‘Black’ weather or adhesion day

- proposing a review of RIS-8040- TOM, ‘Low Adhesion between the Wheel and the Rail - Managing the Risk’ (issue 1, December 2016) to include additional information or a description on how to identify an HRLA location, the factors that must be considered in the site-specific risk assessment process and providing guidance on the control measures to apply in the event of degraded or exceptional conditions.

Great Western Railway

349 GWR reported it has taken the following actions:

a. Reviewed the content of its train driver briefing material to ensure material meets the standards set out in the SCSG’s ‘GB Rail Approach to Managing Low Adhesion’ document (see paragraph 353).

b. Ensured information on HRLA sites (as identified using the new RIS-0840-TOM methodology) is available for its train drivers and confirmed with Network Rail Wessex route that low adhesion signage for each location is present.

c. Provided clarity of wording on braking instructions for its train drivers, and rebriefed the requirements for running brake tests and other driver actions in low adhesion conditions.

d. Ensured the process for late notice notification of ‘red’ and ‘black’ adhesion risk days is effective, including notification if the railhead treatment MPV has been delayed or cancelled.

e. Driver managers have been instructed to brief new drivers on assessing autumn risks. Driver managers have received ‘Brief the briefer’ training to support this strategy. New drivers will also have to complete a revised training session. All other drivers will be required to read and acknowledge that they have received and understood the briefing document issued on a bulletin.

f. Undertaken to audit items (a) to (e) regularly to provide assurance that information has been understood.

Other industry bodies

RSSB

350 As a result of the joint industry investigation, Network Rail and SWR had further discussions with RSSB. In June 2022, RSSB revised Rail Industry Standard RIS-8040-TOM, ‘Managing Low Adhesion’ to issue 2. This revision incorporates relevant content from issue 1 of RIS-8040-TOM and GEGN8540, ‘Guidance on Low Adhesion between the Wheel and the Rail - Managing the Risk’ (issue 2, June 2015). The revised standard includes a simple structured framework (figure 48) and clarifies the responsibilities of the infrastructure owner and train operator in preparing for autumn. It also provides guidance for infrastructure managers to develop, implement, monitor and review the effectiveness of site-specific plans to manage low adhesion at high risk sites and to assist train operators in controlling low adhesion risks and improving safety and performance in low adhesion conditions.

351 RSSB discussions with SWR also led to further changes to RIS-8040-TOM in respect of low adhesion signage. Additionally, it now requires that when control measures are identified as ineffective or unavailable, such as missed runs of an MPV or RHTT, or where planned vegetation work has not been undertaken, the infrastructure manager shall implement alternative mitigation measures without delay.

352 RSSB has delayed the 12-month post-publication review of RIS-8040-TOM to allow for any recommendations identified from the RAIB investigation into the accident at Salisbury to be included in the review.

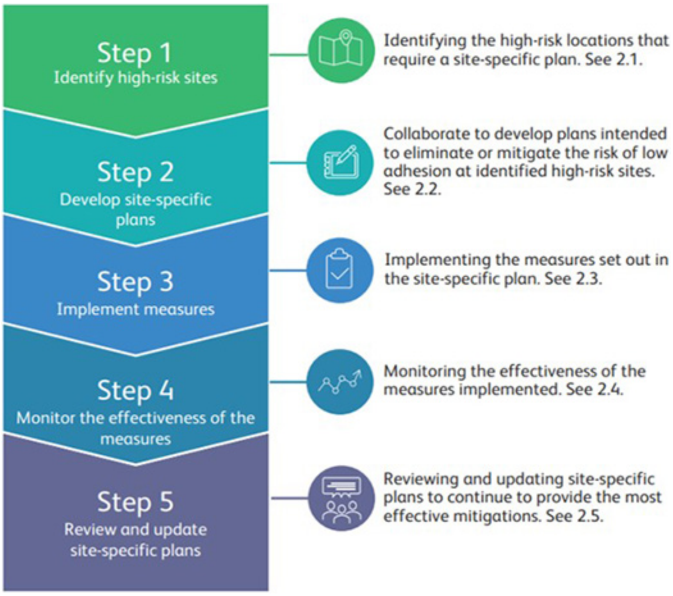

Figure 48: Diagram within Rail Industry Standard RIS-8040, 'Managing Low Adhesion'.

Seasonal Challenge Steering Group

353 The Seasonal Challenge Steering Group (SCSG), a working group of industry professionals and academics, issued a document 'GB Rail Industry Approach to Railhead Adhesion Management' (version 1.1, May 2022). The document sets out the recommended approach to the management of railhead adhesion on the rail network using proven control measures and potential future control measures currently being developed by the rail industry.

Rail Delivery Group

354 Following RSSB research project T1107 'Trials of sanders and sand laying rates' (paragraph 221) undertaken by the Adhesion Research Group, the Rail Delivery Group prepared a national business case for retrofitting variable rate sanders (single and double) to mainline trains, funded by the performance innovation fund (PIF).

355 Following this research, several successful PIF applications were made by:

a. Northern Trains to retrofit double variable rate sanders to their class 323 fleet

b. ScotRail to retrofit double variable rate sanders to their Class 170 fleet

c. SWR to retrofit single variable rate sanders to their class 158 and class 159 fleet during 2023.

Office of Rail and Road (ORR)

356 In December 2021, ORR issued an improvement notice to Network Rail. The notice required Network Rail to:

a. Review all available data sources and identify those which can usefully help to shape or refine the deployment of railhead contamination risk controls.

b. Have in place and act upon an up-to-date autumn risk assessment.

c. Review the extent, type, frequency and speed of railhead treatment operations with a view to optimising the allocation of treatment resource according to identified risk. The review will include consideration of the risk of contamination being transferred into untreated sites and what action will be taken in the event of a missed or deferred planned railhead treatment.

d. Review the vegetation control programme with the aim of ensuring that it is aligned with the need for railhead contamination risk control, as identified above.

e. Demonstrate there is effective communication between the relevant disciplines involved in vegetation management and control of seasons risk. Recognising legislative constraints during the bird nesting season, implement a plan to undertake the highest priority vegetation clearance.

f. Reassess the purpose and value of sample site inspections by MOMs and confirm arrangements to enable any required safe access to the track. If sample site inspections are a useful part of risk management, provide the appropriate level of resource and review how inspections are prioritised to those sites where lost adhesion presents a greater risk of collision or derailment.

g. Review the effectiveness of the use of autumn adhesion forecasting in shaping local responses and providing information in a useable format to train operating companies and other operations stakeholders.

h. Have in place arrangements to undertake assurance on the effectiveness of autumn controls.[41]

357 ORR has reported that Network Rail has since complied with the improvement notice and has taken action to manage the risk from adverse railhead conditions caused by leaf fall. The actions taken include:

a. Engaging with stakeholders and reviewing data to update its risk assessments and identify new and existing sites at high risk of low adhesion.

b. Targeted vegetation removal work at the highest risk sites.

c. Implementing changes to the railhead treatment programme including revised treatment circuits and speed, and the trialling of new treatment products.

d. Strengthening of the mitigation process when railhead treatment is missed.

e. Reviewing, publishing and briefing the autumn working arrangements to relevant people. The arrangements include the inspection of high risk sites and audits of railhead treatment effectiveness.

[41] A copy of the improvement notice can be found at: https://orrprdpubreg1.blob.core.windows.net/docs/IN-KL-20211224-01%20Network%20Rail%20improvement%20notice.pdf.

f. Strengthening assurance arrangements for autumn management, including engaging in the planning of future engineering works with the aim of planning engineering work around the railhead treatment circuits and trialling new technology to identify railhead contamination.

Recommendations

358 The following recommendations are made:[42]

1 *The intent of this recommendation is for Network Rail to have autumn working arrangements that more effectively manage the low adhesion risk, as a result of leaf fall.*

Network Rail should consider the findings from this report to inform a review of the processes, standards and guidance documents and supporting management arrangements relating to the management of leaf fall low adhesion risk. The review should result, where appropriate, in the creation or revision of documents suitable to support Network Rail staff in having an appropriate understanding of the risks when creating autumn working arrangements. It should also identify the necessary resource and competence required for their effective implementation.

The review should examine both the roles of operations and maintenance (track and off track) and specifically include consideration of:

a. leaf fall risk assessments, including consistency in their implementation
b. capture, sharing and tracking of data and planned mitigations, especially those related to vegetation management
c. definition of responsibilities and necessary competences, including knowledge of the factors affecting leaf fall risk and low adhesion from contamination build-up and the effectiveness of mitigation measures
d. required resource to effectively undertake the main roles
e. alignment of the requirements and processes across all related departments to promote a co-ordinated approach and a common understanding of the risks and mitigations.

Network Rail should ensure that any revised processes, standards and guidance are produced to a timebound plan, and supported by appropriate training and briefing and that this includes any contracting staff involved in the process (paragraphs 322a (i) and (ii), and 323a (ii) to (vi)).

[42] 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 and Road to enable it to carry out its duties under regulation 12(2) to:

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

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

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

2 *The intent of this recommendation is for Network Rail to have seasons delivery specialists that are more effective in managing Network Rail's seasonal risk.*

Network Rail, building on the work that has already started in this area, should develop an appropriate competency framework for the role of the seasons delivery specialist.

This framework should include:

a. a job description that accurately reflects the responsibilities of the role

b. the necessary technical skills required to undertake the role effectively

c. the necessary non-technical and management skills needed to undertake the communication and co-ordination required of this role

d. appropriate training material

e. arrangements to confirm that staff have achieved, and continue to have, the required level of competence.

Network Rail is to arrange for provision of the necessary staff to fulfil the roles and develop a time-bound programme for implementation of the associated training, supported by suitably qualified assessment staff (paragraphs 322a (i) and (ii) and 323a (i), (ii), (v) and (vii)).

3 *The intent of this recommendation is that Network Rail off track staff are sufficiently competent and confident to undertake the tasks assigned to them by Network Rail standards.*

Network Rail should produce a time-bound programme to train and assess the competence of off track maintenance staff in the requirements of standard NR/L2/CIV/1000/01 Module 01, 'Competence Management for Drainage and Lineside' (paragraphs 322a (i) and 323a (i), (ii) and (vii)).

4 *The intent of this recommendation is for Network Rail to be able to make more effective decisions regarding the management of emerging and potential low wheel/rail adhesion conditions.*

Network Rail, working in co-operation with train operators, Rail Safety and Standards Board and other relevant stakeholders, should undertake research into real-time data that could be used to give an indication of the wheel/rail adhesion conditions on its network and how this could be used to support operational decisions to implement mitigation measures.

This review should include consideration of the following:

a. monitoring data, including that drawn from on-train data recorders, wheel slide protection activity, and records of wrong side track circuit failures

b. reports of low adhesion from train drivers and staff

c. weather and low adhesion forecasts.

This review should take account of good practice in other parts of the rail sector both in the UK and abroad (paragraphs 322a (ii) and 323a (vi).

5 *The intent of this recommendation is for Network Rail to improve wheel/rail adhesion conditions through the application of improved understanding of the effectiveness of railhead treatment regimes.*

Network Rail should undertake research to better understand:

a. the factors that affect the rate of build-up of leaf fall contamination, for instance, the environment, meteorological conditions, topography, tree species and railway operations

b. the relationship between different types of contamination and low railhead adhesion

c. the effectiveness and longevity of currently available alternative railhead treatment regimes.

The findings from this research are to be used to support the seasons delivery specialist in decision-making relating to the necessary frequency of railhead treatment and understanding the impact of missed or delayed treatment (paragraphs 322a (ii) and 323a (vi).

6 *The intent of this recommendation is to enable the effective assessment by Network Rail of the risk of overrun at signals which have HRLA sites on their approach.*

Network Rail should review its signalling standard NR/L2/SIG/14201/Mod04, 'Signalling Risk Assessment Handbook' to ensure that signal overrun risk assessments appropriately consider the impact of any high risk of low adhesion sites on approach to the signal. Network Rail should also consider if the reassessment of signal overrun risk is required when a new high risk of low adhesion site is identified on approach to any signal capable of displaying a red aspect.

Any revised standard or process should be suitably briefed to all relevant parties and consideration should be given to whether a revised overrun risk assessment against the new standard should be required where existing signals capable of displaying a red aspect have a high risk of low adhesion site on their approach (paragraph 324a).

7 *The intent of this recommendation is to reduce the risk of overrunning signals at danger where there is a line speed change on the approach after the preliminary caution signal.*

Network Rail should review the decision not to retrospectively apply technical instruction TI022 'Provision of TPWS at signals' issue 4 to existing signals. Should retrospective application of TI022 be found appropriate, Network Rail should implement the required changes to existing Train Protection and Warning System equipment (paragraph 324b).

8 *The intent of this recommendation is that South Western Railway drivers are able to identify areas of low adhesion and report them, if appropriate.*

South Western Railway should review its arrangements for training and briefing drivers to ensure that they are able to effectively identify areas of low adhesion and that they report them if appropriate. This review should specifically understand the effectiveness of the relevant provisions of the railway Rule Book in informing drivers as to the requirements for reporting low adhesion, as well as other methods. South Western Railway should evaluate its processes for monitoring and reviewing the reporting of low adhesion by drivers to ensure that these arrangements remain effective (paragraphs 322b and 323b).

This recommendation may apply to other transport undertakings.

9 *The intent of this recommendation is for industry to realise the potential benefits of future technologies to enable trains to better cope with low wheel/rail adhesion when braking.*

The Rail Delivery Group working with the train operating companies and Rail Safety and Standards Board should create a framework and mechanism for the assessment of future technologies to enable trains to better cope with low adhesion when braking.

The framework should set out criteria and establish the process for cost benefit analysis to apply to the assessment of future technologies as they arise (paragraph 322c).

10 *The intent of this recommendation is to minimise the risk that passengers are unable to evacuate from class 158 and 159 carriages.*

Porterbrook, Angel Trains and Eversholt Rail, working in conjunction with the operators of class 158 and class 159 trains, should review the design of the internal sliding doors on these carriages and determine if there is a practicable means to prevent these doors becoming jammed in the event of a collision.

They should develop a time-bound plan to implement measures identified by this review (paragraph 325b).

Appendices

Appendix A - Glossary of abbreviations and acronyms

AWG	Adhesion Working Group
AWS	Automatic Warning System
CCTV	Closed-circuit television
DMU	Diesel multiple unit
DVRS	Double variable rate sanding
EWAT	Extreme weather action team or Extreme weather action teleconference
FFCCTV	Forward-facing closed-circuit television
GBW	Geographic block working
GWR	First Greater Western Ltd, trading as Great Western Railway
HRLA	High risk of low adhesion
HST	High speed train
IIT	Infrastructure Intelligent Technicians
MDU	Maintenance delivery unit
MOM	Mobile operations manager
MPV	Multi-purpose vehicle
ORR	Office of Rail and Road
OSS	Overspeed system
OTDR	On-train data recorder
PDP	Professional driving policy
PIF	Performance innovation fund
RHTT	Railhead treatment train
ROLA	Report of low adhesion
RSSB	Rail Safety and Standards Board
SAE	Senior asset engineer
SDS	Seasons delivery specialist
SORAT	Signal Overrun Risk Assessment Tool
SPAD	Signal passed at danger

SWR	First MTR South Western Trains Ltd, trading as South Western Railway
TGA	Traction gel applicators
TME	Track maintenance engineer
TPWS	Train Protection and Warning System
TSS	Train stop system
WAIF	Work arising information form
WSTCF	Wrong side track circuit failure
WICC	Wessex Integrated Control Centre
WSP	Wheel slide protection
WSPER	WSP Evaluation Rig

Appendix B - Sources of evidence

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- information taken from the train's OTDR and remote condition monitoring equipment
- examination of the carriages quarantined
- CCTV recordings taken from train 1L53
- site photographs and measurements
- weather reports and observations at the site
- research and analysis
- a review of previous RAIB investigations that had relevance to this accident.

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