



Rail Accident Investigation Branch

Rail Accident Report



**Near miss involving track workers near Hest
Bank, Lancashire
22 September 2014**

Report 08/2015
July 2015

This investigation was carried out in accordance with:

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

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Preface

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

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

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

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

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

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

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

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

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Near miss involving track workers near Hest Bank, Lancashire, 22 September 2014

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Summary

During the afternoon of Monday 22 September 2014, a group of nine track workers repairing a section of the West Coast Main Line south of Hest Bank level crossing, near Lancaster, narrowly avoided being struck by a southbound passenger train. Their site of work was located on a bend which restricted visibility of approaching trains. Warning of approaching trains was intended to be given by lookouts, located remotely with good visibility of the track, using a radio-based lookout operated warning system (LOWS). The system had been working normally prior to the incident, but the workgroup did not receive a warning for the incident train.

The track workers saw the approaching train with just enough time to clear the track before it passed them while travelling at 98 mph (158 km/h). They were shaken by the incident, but not physically injured. All work on the site was stopped for the remainder of the shift.

The incident was caused because a lookout did not give a warning, either because he operated the wrong switch on his radio transmitter by mistake, or because he forgot about the need to send a warning during an intended delay period between seeing the train and operating the warning switches. This delay was because he was positioned on a long section of straight track and could see approaching trains for significantly longer than the time required for the workgroup to move into a position of safety. A previous RAIB recommendation intended to mitigate this risk had not been implemented due to administrative errors. It is probable that the lookout's vigilance had degraded as he had been working continuously for almost two hours. Although unrelated to the incident, the RAIB identified that a safety-critical element of the LOWS circuitry was not subject to routine testing.

The RAIB has made two recommendations to Network Rail covering the management of working time for tasks which depend on vigilance, and the circumstances in which LOWS should be used.

Introduction

Key definitions

- 1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.
- 2 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The incident

Summary of the incident

- 3 At 14:24 hrs on Monday 22 September 2014, nine track workers were involved in a near miss with the 12:12 hrs Edinburgh Waverley to Manchester Airport service (train reporting number¹ 1M97), operated by First TransPennine Express (FTPE). The incident occurred at a site of work located on a curved section of track south of Hest Bank on the West Coast Main Line between Carnforth and Lancaster (figure 1). The train was travelling on the *up line* in the up (southwards) direction at 98 mph (158 km/h).
- 4 The *workgroup*, comprising eight contract staff and a Controller of Site Safety (COSS) employed by Network Rail, were repairing a track fault on the up main line on a small *underbridge*. The workgroup was working on a line open to trains, with protection provided by a lookout operated warning system (LOWS). The LOWS control unit, located at the site of work and supervised by a LOWS controller, was intended to give a visual and audible warning at least 25 seconds before a train approached. This allowed the track workers sufficient time to clear the track and move to a designated *position of safety* located off the bridge and next to the up line. The warnings were being triggered by lookouts positioned north and south of the site using lookout operated transmitter units. The LOWS was working normally prior to the incident, but the workgroup did not receive a warning for the incident train before it arrived at the site of work.
- 5 The COSS saw the train approaching on the up main line when it was just over three seconds away and shouted an urgent warning. Staff took rapid evasive action, but some members of the workgroup were on the bridge and were unable to reach the designated position of safety, instead pressing themselves against the bridge parapet (figure 2). The last member of the workgroup was not clear of the line until about one second before the train passed (figures 2 and 9).

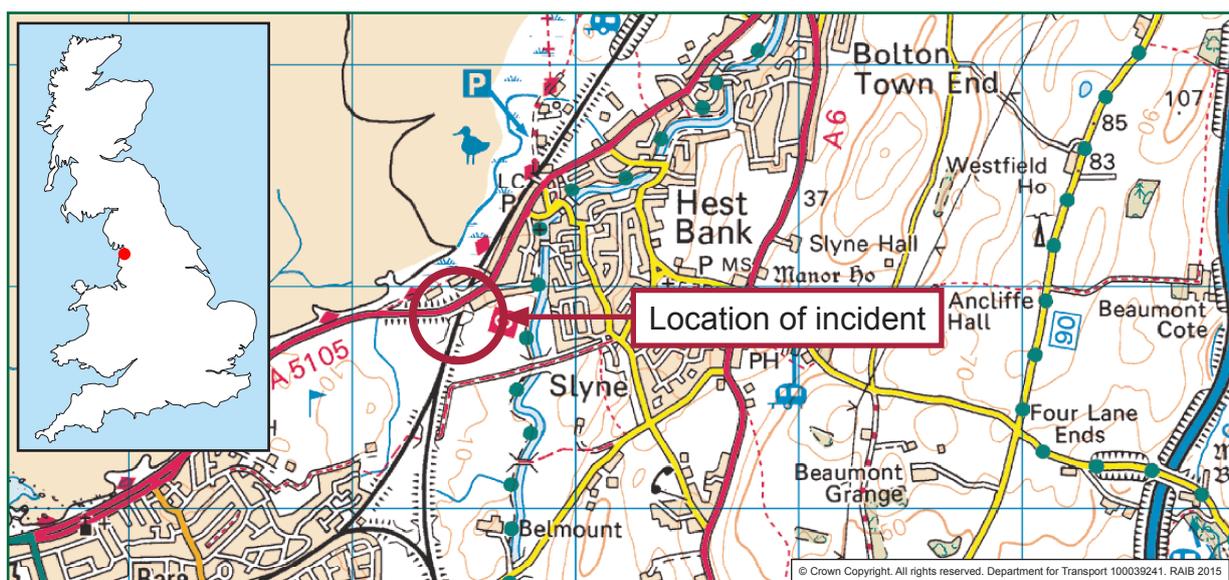


Figure 1: Extract from Ordnance Survey map showing location of the incident

¹ An alphanumeric code, known as the 'train reporting number', is allocated to every train operating on Network Rail's infrastructure.



Figure 2: Image of workgroup from forward-facing CCTV camera fitted to train 1M97 (courtesy of FTPE)

- 6 There were no physical injuries, but the track workers were shaken. The COSS decided that work would cease and made arrangements for the workgroup to return to the access point at Hest Bank level crossing in a controlled manner. This was done without relying on LOWS, although it continued to operate until all staff were off the track.

Context

Location

- 7 The site of work was located at 2 miles 52 chains² on the West Coast Main Line, 780 metres (853 yards) south of Hest Bank level crossing (Engineer's Line Reference CGJ7). At this location, the up and down main lines run parallel to the single line Down & Up Morecambe (North Curve) leading to Bare Lane Junction. The main lines, on which trains can travel at up to 125 mph (201 km/h), are electrified with 25 kV overhead equipment. An overhead neutral section is located 280 metres south of the site of work. The North Curve, on which trains can travel at up to 45 mph (72 km/h) in either direction, is not electrified (figure 3).
- 8 Travelling south from Carnforth, the up and down main lines approach Hest Bank level crossing on a straight section of track over 4 km long. Immediately after the level crossing, the North Curve branches off the down main line and the three lines curve to the left, passing under a bridge carrying the A5105 road over the railway about 110 metres before the site of work. The abutment of this bridge restricted the train driver's view and meant that he could not see the track workers until the train was about 150 metres from them. About 1200 metres beyond the site of work, the railway from Morecambe joins the main line at Morecambe South Junction.

² The mileage is measured from Lancaster station; one chain is equal to 22 yards (approximately 20 metres).

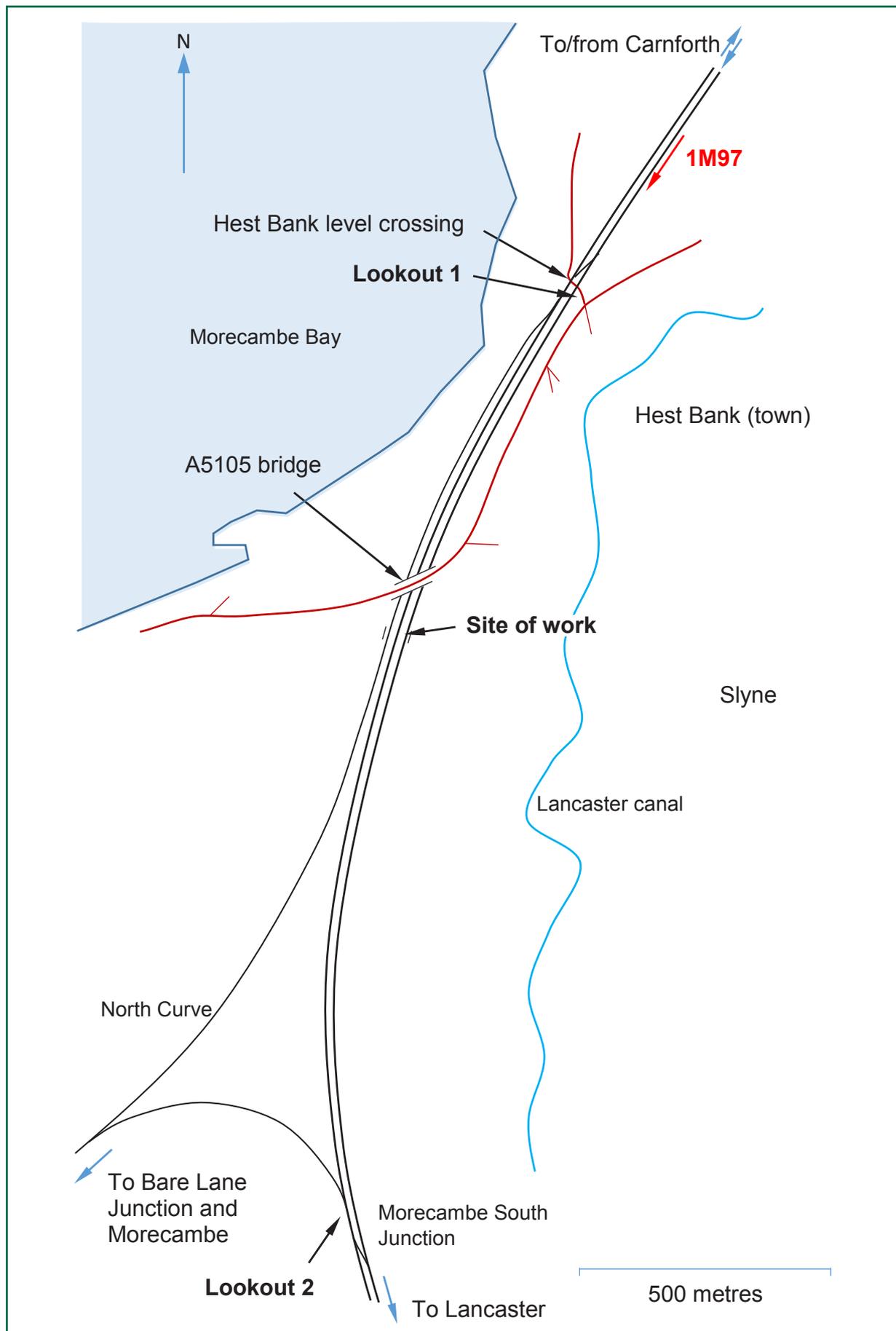


Figure 3: map showing track layout and location of staff

Organisations involved

- 9 Network Rail: owner and maintainer of the infrastructure, and employer of the COSS, LOWS controller and LOWS lookouts.
- 10 SW Global Resourcing Ltd: employer of the eight contract staff involved.
- 11 First/Keolis Transpennine Holdings Limited, operating as First TransPennine Express (FTPE): operator of the class 350/4 train involved and employer of the train driver.
- 12 Zöllner signal GmbH: manufacturer of the LOWS equipment based in Germany, which was maintained by its Zöllner UK subsidiary.

Train involved

- 13 The train was a four car class 350/4 electric multiple unit, number 350402, capable of running at 110 mph (177 km/h). At the time of the incident, FTPE class 350/4 units were limited to 100 mph (161 km/h) on this section of the West Coast Main line for reasons not related to the incident.

Rail equipment/systems involved

- 14 The track workers were using shovels, a *track gauge* and a small jack. Their work involved jacking a rail and placing ballast under the sleeper at positions instructed by the COSS, a technique known as *measured shovel packing*. The purpose of this activity was to correct a track geometry fault (*twist fault*).

LOWS equipment

- 15 The LOWS equipment comprised a Zöllner Autoprowa ZPW LOWS control and warning unit located at the site of work and two (version 1.4) ZFH lookout operated transmitter units with booster aerials.
- 16 The Zöllner ZPW-LOWS was first used on Network Rail infrastructure in early 2008 and was one of two similar LOWS made by different manufacturers and approved for use on Network Rail infrastructure. Both systems gave visual and audible warnings at a site of work triggered by a radio signal transmitted by a lookout who may be positioned away from the site of work in order to obtain the required view of approaching trains (required *sighting distance*) (figure 4). Network Rail purchased Zöllner equipment as it was considered more portable than the alternative. At the time of the incident, Network Rail owned 229 Zöllner ZPW-LOWS sets.
- 17 Each Zöllner ZPW-LOWS set comprised a ZPW control unit incorporating a radio receiver (figure 5) and up to four ZFH lookout operated transmitters (figure 6) equipped with booster aerials, spare batteries and harnesses. The set included a paper log book to record usage, routine testing and faults. The radio system fitted to ZPW-LOWS version 1 equipment is uni-directional, so cannot transmit messages from the ZPW control unit to the lookout's ZFH transmitter. Each set of Zöllner equipment is therefore supplied with dedicated mobile phones which allows communication between the site of work and the lookouts³. The ZPW control unit has an internal data logger which records incoming warnings and system error messages. The ZFH transmitter units do not contain a data logger.

³ As required by Network Rail standard NR/L3/MTC/SE0207 'Use of LOWS equipment'.

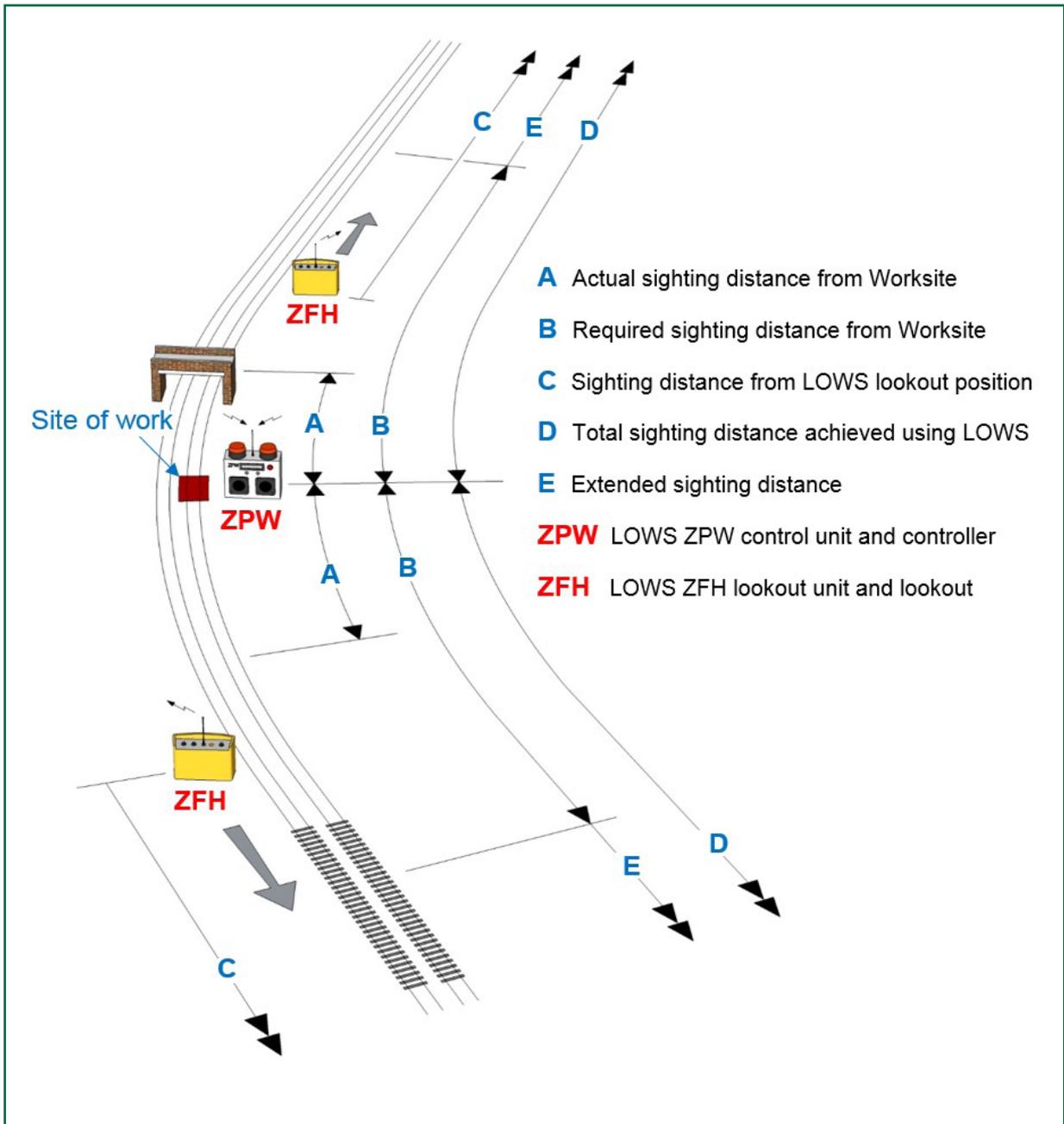
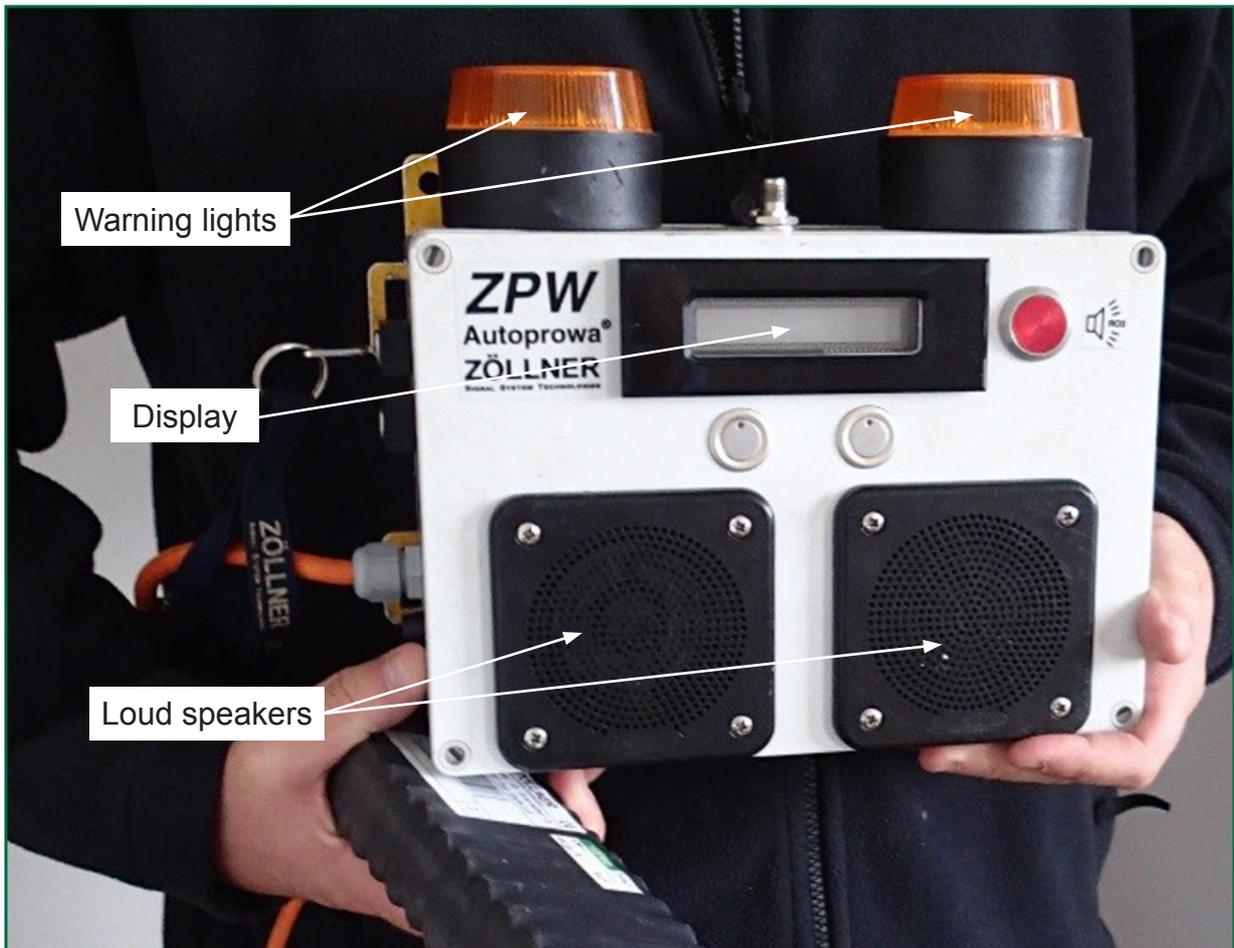


Figure 4: Schematic diagram of LOWS equipment in use

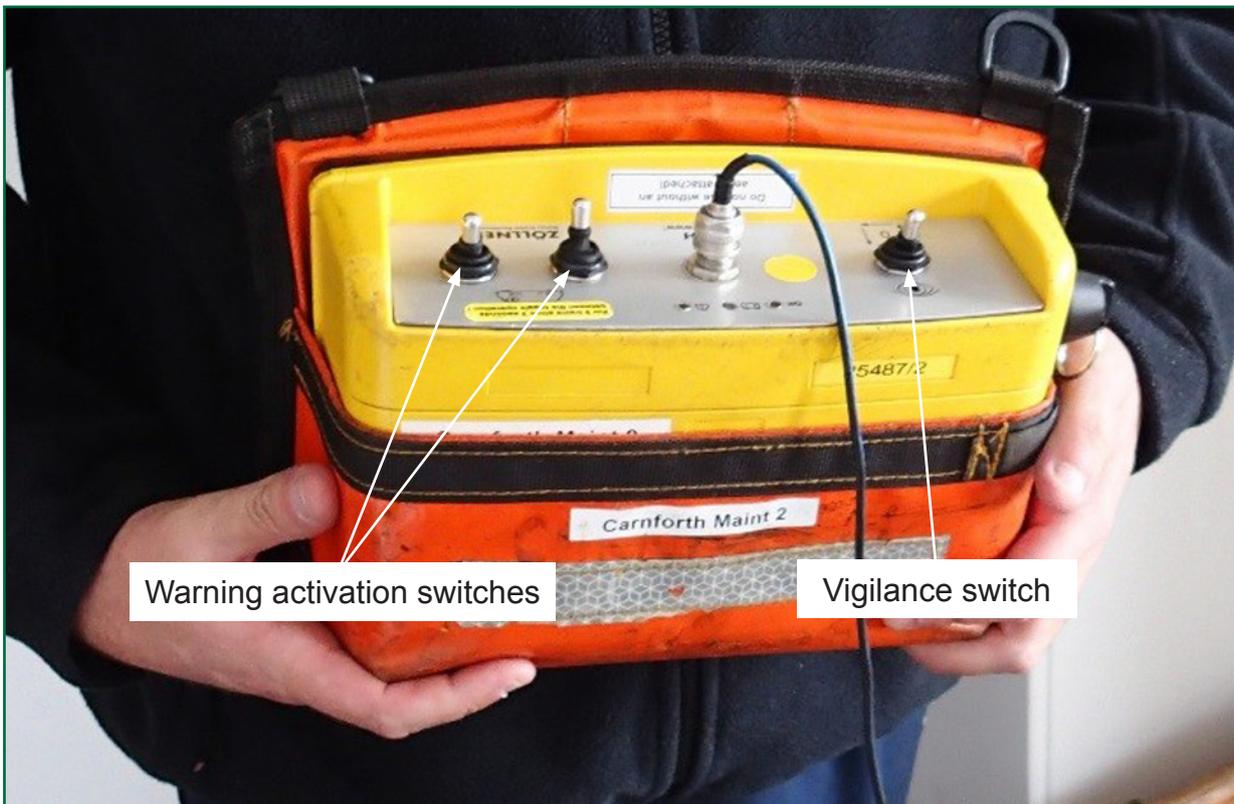


Warning lights

Display

Loud speakers

Figure 5: ZPW control unit with external battery



Warning activation switches

Vigilance switch

Figure 6: ZFH lookout operated transmitter unit

- 18 Since its introduction, the ZPW-LOWS software has been upgraded to address issues identified by Network Rail's internal investigations into previous incidents and the Office of Rail Regulation (ORR)⁴. The set-up protocol, used each time the ZPW-LOWS is switched on, was amended following intervention by the ORR in May 2008. In May 2010, ZPW-LOWS version 1.4 software was introduced, and all Network Rail's sets were subsequently upgraded to this version.
- 19 When switched on, the ZPW-LOWS performs a self-test. The LOWS controller initiates the system set-up by contacting each lookout in turn, using the dedicated mobile phones, and requesting that each lookout sends a test warning as if a train was approaching. When the warning is received, the ZPW control unit displays its unique radio code (key) number to indicate which ZFH lookout unit is in contact. The LOWS controller is required to acknowledge and cancel the warning.
- 20 When operational, the ZFH lookout unit displays a yellow flashing LED. A lookout gives warning of an approaching train by operating a pair of spring-loaded toggle switches (warning activation switches) mounted on the top left-hand side of the ZFH lookout operated transmitter. These have to be pushed in opposite directions, simultaneously, to activate a normal warning. When the toggle switches are operated, the ZFH unit emits two short bleeps and a second LED indicator lights up. A lookout receives no confirmation that a warning has been received or acknowledged at the control unit. If a lookout is unsure whether he has given a warning, he can send a second warning and then contact the LOWS controller by the dedicated mobile phone if necessary to explain what has happened.
- 21 When a warning is received, the ZPW control unit flashes its warning lights and emits a loud warning sound at between 102 and 110 dB (automatically adjusting for ambient noise levels). The controller can acknowledge the warning to cancel the sound, but the warning lights cannot be cancelled for at least 20 seconds. There is an emergency button on the control unit to allow the controller to initiate an alarm sequence.
- 22 The ZPW-LOWS is designed to mitigate the risk of a warning not being received because of a problem affecting either the lookout or the radio signal (refer to paragraph 23). In each case, the software is designed to cause the ZPW control unit to fail-safe and go to warning mode (ie to give a visual and audible warning using flashing lights and warning sound) so that any staff being protected can move to a position of safety. As a further safeguard, the ZPW system processes the incoming signal using two separate independent channels. Each channel constantly checks that the other is working correctly. If the two channels do not agree, or one channel stops working, the other channel triggers the visual and audible warning.
- 23 ZPW-LOWS version 1.4 equipment incorporates safety functions to ensure a warning is given at the site of work if any of the following potentially unsafe conditions occur:
 - a. If an operational ZFH lookout unit is tilted for more than three seconds, for example if the lookout has fallen or collapsed, it will sound an audible alarm to alert the lookout. If the lookout fails to respond and return the unit to an upright position within a further five seconds, an automatic warning is transmitted to the ZPW control unit.

⁴ Now known as the Office of Rail and Road (ORR).

- b. If the lookout fails to operate the vigilance switch (a single sprung toggle switch mounted on the top right-hand side of the ZFH lookout unit) at least once every 20 seconds when the system is active, an alarm will sound to prompt the lookout to do so. If the lookout does not respond to the alarm within five seconds, an automatic warning is transmitted to the ZPW control unit.
 - c. If a single warning activation switch (rather than both switches) on a ZFH lookout unit is operated, this causes an automatic warning to be transmitted to the ZPW control unit.
 - d. If the radio signal from any connected ZFH lookout unit is interrupted for more than four seconds, a radio signal monitoring system within the ZPW control unit activates the warning. The ZFH lookout unit incorporates a five second signal extension function which means that a warning given by the lookout unit is repeated for all radio messages (telegrams) sent out within the five second period following activation of the warning activation switches. The system therefore operates normally provided the radio signal is not interrupted for more than four seconds and should give a warning for any longer interruptions.
 - e. Although the features described in paragraph d) should prevent a warning from the ZFH lookout unit being lost during a radio signal interruption, the system includes an additional function intended to detect a lost warning. Each telegram includes a number count code which increments by one each time a warning is sent. The ZPW control unit monitors this number and gives a site warning if the number changes without receipt of a telegram warning that a train is approaching.
- 24 If a safety function triggers an alarm, a message identifying the error is displayed on the ZPW control unit's screen and recorded in its data logger. The visual and audible site warning is triggered and continues until acknowledged and cancelled by the LOWS controller. The system then needs to be reset before it becomes operational again.

Staff involved

- 25 The COSS, the LOWS Controller and the two LOWS lookouts worked for Network Rail's Lancashire and Cumbria delivery unit, based at Carnforth depot.
- 26 The eight contract staff were employed by SW Global Resourcing Ltd. The staff had worked in track maintenance for periods ranging from eight months to 10 years.

External circumstances

- 27 Weather records for Bolton-le-Sands, located between Carnforth and Hest Bank, indicate that conditions were dry and mild (18°C), with a 10 mph southerly wind. The rearward facing CCTV camera on the incident train showed that no haze, glare or other environmental factors were impairing the view of a lookout looking north from Hest Bank level crossing (figure 8).

The investigation

Sources of evidence

28 The following sources of evidence were used:

- information provided by witnesses;
- train driver's statement to his employer;
- information taken from the train's on-train data recorder (OTDR) and forward and rear facing closed-circuit television (CCTV) equipment;
- Network Rail signalling data, including CCF (Control Centre of the Future) data to establish precise train positions and timings.
- data logger records from the ZPW-LOWS involved in the incident, and the results of subsequent testing of this equipment;
- weather reports;
- Network Rail standards, LOWS working instructions and data on previous similar incidents;
- Network Rail's internal investigation report into this incident;
- a review of previous RAIB investigations that had relevance to this incident; and
- a report commissioned by Network Rail from the Health and Safety Laboratory into a previous incident at Crag Bank near Carnforth in April 2014 which examined the functionality of Zöllner LOWS version 1.4 equipment.

The sequence of events

Events preceding the incident

- 29 A track fault had been identified by a Network Rail *new measurement train* (NMT) while undertaking a routine track assessment run on 9 September 2014. However, work to correct the fault using measured shovel packing was not planned until the morning of the incident (22 September).
- 30 The Carnforth depot Section Planner produced a *safe system of work pack* (SSoW pack) on the morning of 22 September covering two sites where work was to be undertaken that day, one near Lancaster and the other near Hest Bank. Contrary to Network Rail's planning process⁵, the SSoW pack was not checked by the section manager or section supervisor, who were the only members of staff authorised to act as the *responsible manager*. As the work was due to be undertaken during the same shift, the SSoW pack should also have been reviewed by a more senior line manager before being issued to the COSS. Instead, the SSoW pack was issued directly to the COSS who reviewed both parts and signed it to indicate his acceptance of the proposed methods of working. He did not have the opportunity to review the pack a shift in advance, as should normally be the case.
- 31 Standard NR/L2/OHS/019 'Safety of people working on or near the line' included a hierarchy of safe systems of work (appendix C). Staff responsible for planning work on the track were required to select the highest achievable safe system of work consistent with the nature, location, and duration of the task. A planned *possession or line blockage* was the preferred option. The lower part of the hierarchy included four options in which trains continue to run on the affected lines, and staff are instructed to leave the task and move to a position of safety when a warning of an approaching train is given. In descending order of preference these options were: *Automatic Track Warning System* (ATWS); *Train Operated Warning System* (TOWS); *Lookout Operated Warning System* (LOWS). The least preferred option was a warning given by one or more Lookouts. This least preferred option included the use of flags where necessary to communicate between a lookout at the site and any lookouts positioned further away because of insufficient visibility of approaching trains.
- 32 LOWS was selected as the protection method for the work at both sites on 22 September because the required *warning time* was greater than the available sighting distance and ATWS and TOWS were not available. Use of LOWS also allowed more working time than would be available if work was limited to the times that the line could be blocked between trains. At Morecambe South Junction, line blockages during the middle of the day are typically available for up to 20 minutes according to the local 'Green Zone Guide' published by Network Rail. However, staff have stated that several trains are sometimes required to pass before a block can be granted by the signaller. The COSS had previous experience doing work of this type using line blockages, and had found that the short working periods available made it difficult to complete work.

⁵ Network Rail standard NR/L2/OHS/019 'Safety of people working on or near the line' Issue 8 September 2010.

- 33 The LOWS Controller and lookouts were members of Carnforth depot's rail testing team. They were rostered to work a four-day week and had volunteered to work on what would normally have been a rest day. None had worked on the previous day. They were experienced users of Zöllner ZPW-LOWS equipment and had a good working knowledge of the Hest Bank area. LOWS was regularly used as a method of protection by Carnforth depot staff because the high speed of trains and number of curves restricted the sighting distance available in many locations.
- 34 The track workers had been provided by SW Global Resourcing Ltd to undertake preventative maintenance under the supervision of a Network Rail COSS. This Mondays-only arrangement had been running for a month prior to the incident in order to reduce the number of outstanding track defects.
- 35 On 22 September, the COSS and workgroup had completed a morning session on the site near Lancaster (paragraph 30). This had lasted just over two hours and used the same LOWS equipment as protection. Prior to the afternoon session, the COSS had established that, in order to give the required warning time at the afternoon's site of work, one LOWS lookout would need to be positioned beside Morecambe North Curve to give warnings for southbound (up) trains (Lookout 1), and the other near Morecambe South junction to give warnings for northbound trains (Lookout 2). Therefore, after a lunch break, Lookout 2 went directly to his designated position at Morecambe South junction. This was close to where he had been located that morning, but he was now going to be looking out for trains approaching in the opposite direction.
- 36 The remainder of the workgroup assembled at Hest Bank level crossing for the afternoon session. The COSS then briefed these staff who signed a 'Record of Work Arrangements Briefing Form' (RT9909) to acknowledge that they had received and understood the briefing. The form gave information on the access point, speed of trains, required warning time, and stated that the planned method of protection was the use of LOWS.
- 37 At 12:28 hrs, the LOWS Controller switched the ZPW control unit on and established a radio connection with both ZFH lookout units. Once the LOWS had been set up and tested to confirm it was responding correctly, the COSS and workgroup accessed the railway at Hest Bank level crossing. Lookout 1 accompanied the workgroup along a safe walking route adjacent to the North Curve, and parallel to the main lines. Lookout 1 stopped at his designated lookout position beside the North Curve while the remainder of the workgroup continued round the curve and reached the site of work after crossing all three lines under LOWS protection.
- 38 Lookout 1 subsequently contacted the LOWS Controller and obtained permission to reposition himself to avoid having to stand by a wasps' nest. He moved to a new position next to the up main line about 10 metres south of Hest Bank level crossing, a position which he had used previously when acting as a LOWS lookout. There was no interruption to the radio signal and the LOWS remained active during this move. From his new location at the end of a long straight section of track Lookout 1 could see an approaching southbound train when it was at least 2.5 km away (about 45 seconds for the fastest train).

- 39 At 13:40 hrs, after the LOWS had been operational for 72 minutes, the ZPW control unit gave a visual and audible warning to indicate a low battery. After all staff had moved to the designated position of safety, the LOWS Controller shut the system down. After two failed attempts to restart it, a replacement battery was requested from Carnforth depot to allow work to continue.
- 40 At 14:12 hrs, the replacement battery was in place and the LOWS Controller restarted the system and successfully received test warnings from both lookouts. During the stoppage, Lookout 2 was contacted and advised to stand down, but Lookout 1 was not notified due to an oversight, and he continued to look out for trains throughout this period. The incident train was the first to approach in the up direction after the LOWS was restarted by which time, Lookout 1 had been working for 1 hour 55 minutes without a break.

Events during the incident

- 41 At 14:23:51 hrs⁶, train 1M97 passed Hest Bank level crossing travelling at 101 mph (162 km/h), and then passed Lookout 1 standing beside the up main line approximately 10 metres beyond the crossing. The CCTV recordings from the train shows that he was in position next to the track and facing the train when it passed (figures 7 and 8). It shows him wearing the ZFH lookout unit on a neck strap and holding onto his hard hat to prevent this being blown off by the train. The train driver states that he gave a warning using the train's horn, and that the lookout had acknowledged this by raising his arm as it approached.



Figure 7: Image of Lookout 1 from forward-facing CCTV camera fitted to train 1M97 (courtesy of FTPE)



Figure 8: Image of Lookout 1 from rear-facing CCTV camera fitted to train 1M97 (courtesy of FTPE)

- 42 Fourteen seconds later, at 14:24:05 hrs, train 1M97 approached the A5105 road bridge (figure 9). The driver states that passing under the bridge, he saw staff working directly in the path of his train and sounded the horn. The COSS, who was placing ballast under the sleepers with a shovel while the cess rail was raised on the jack, saw the train at about the same time and immediately shouted a warning. The train at this point was just over three seconds away. The COSS had not heard the train approaching and the LOWS had not given a warning. The workgroup rapidly evacuated the tracks, dropping tools and leaving the jack in position (figure 10). The jack collapsed under the weight of the passing train (as intended by the jack's design). A witness reports that the train hit a shovel.

⁶ Clock times from incident train's On Train Data Recorder (OTDR), verified using signalling records.



Figure 9: Images of workgroup from forward-facing CCTV camera fitted to train 1M97 while approaching under the A5105 bridge (courtesy of FTPE). Clock times are based on OTDR data.



Figure 10: Image of workgroup from rear-facing CCTV camera fitted to train 1M97 showing yellow jack beneath right-hand rail (courtesy of FTPE)

- 43 The location of the site on a small underbridge fitted with *limited clearance* signs meant that there was no immediately adjacent position of safety. Four members of the workgroup were trapped on the bridge and clung to the bridge parapet to remain clear of the train which, because it had been coasting since just after passing Hest Bank level crossing, was travelling at a slightly reduced speed of 98 mph (158 km/h) as it passed. The train's OTDR indicates that the driver applied the brake two seconds after passing the workgroup, an action consistent with the driver slowing the train to stop at the next booked stop, Lancaster, where he reported a near miss with the track workers.

Events following the incident

- 44 Immediately after the near miss, the LOWS controller showed the ZPW control unit to the COSS to confirm that its display showed 'status ok', indicating that the system was operational and that a warning had not been received. The COSS checked that all staff were unhurt. A short time later, both lookouts were instructed to send test warnings to verify that LOWS was working correctly. The LOWS control unit gave the normal warning response to these test warnings.
- 45 The COSS stopped all work immediately and prepared to take the workgroup back to Hest Bank level crossing, leaving the track with some ballast removed but in a safe condition. He and the LOWS Controller used mobile phones to maintain contact with both lookouts to enable the workgroup to cross the tracks to the safe walking route without relying on the LOWS equipment. The COSS reported the incident to Network Rail's fault control by mobile phone. LOWS continued to operate until the COSS and work group had returned to Hest Bank level crossing and were off the track.
- 46 As Lookout 2 had no involvement in this incident, for the remainder of this report, Lookout 1 will be referred to as 'the Lookout'.

Key facts and analysis

Examination and testing of the equipment involved in the incident

- 47 The ZPW-LOWS equipment involved in the incident on 22 September 2014 comprised ZFH lookout transmitter unit serial number 082621057, and ZPW control unit serial number 083061013. This equipment was subsequently examined and tested by the RAIB and Network Rail, with assistance from Zöllner UK.
- 48 The following conclusions were drawn from examination of the equipment, its log book records from August 2013 to September 2014, and maintenance records from April 2013 to September 2014:
 - a. there was no evidence of the equipment being mistreated and there was no evidence of external damage;
 - b. the set had been serviced at the required intervals and had received its last annual service in July 2014;
 - c. no unusual defects or faults had been recorded during use or servicing; and
 - d. the records showed that the set had received its weekly functional test prior to use on Monday 22 September.
- 49 The equipment was tested using a test plan developed by the RAIB. This was intended to verify the systems' responses to a range of normal and fault scenarios (eg operation of a single warning activation toggle switch, or partial operation of a switch). In every case, a visual and audible warning was triggered at the ZPW control unit together with a message indicating that either a normal warning had been received or a system error had occurred. In each case the response was recorded on the data logger record. It was noted that on the ZFH lookout unit, the vigilance alarm sounded after 18 seconds (ie 2 seconds less than specified in the Zöllner operating manual).
- 50 Testing of the warning telegram number count code was not achieved because this required a warning telegram to be deliberately lost so that the subsequent warning telegram would be received out of sequence. When the ZFH lookout unit was taken out of range in order to 'lose' a warning, this correctly triggered a 'transmission lost' error message and a visual and audible warning before a subsequent message could be sent. The error message 'Error TX warning count', associated with telegram numbering being out of sequence, was obtained while testing rapid operation of the warning activation switches. It is probable that the rapid activation of the switches had resulted in a different count between the ZFH lookout unit and the ZPW control unit. This showed that the message counter was operational.
- 51 The data logger record indicates that the set had been used, without any evidence of a technical malfunction, on 54 occasions between 11 January 2014 and 22 September 2014. This record also confirmed that the weekly functional test had been undertaken prior to use on Monday 22 September as recorded in the log book (paragraph 48).

- 52 The data logger also recorded that during the afternoon session on 22 September 2014, the Lookout had given warnings for all six southbound trains which passed the site while LOWS was operational before the ZPW battery first failed at 13:40 hrs. The times of the warnings correspond with Network Rail's train running data for that period. There is no warning or error message recorded at the time the incident train approached the Lookout at 14:23 hrs. The data logger record also confirms that the ZFH lookout unit was functioning normally when tested immediately after the incident (paragraph 44).
- 53 The lack of error messages on the afternoon of the incident rules out an interruption to the radio signal, or a missing warning telegram, as causes of the incident. Based on this evidence, the RAIB has concluded that the LOWS was working correctly, but the Lookout did not give a warning on this occasion.

Identification of the immediate cause

- 54 The workgroup did not receive a warning of the train before it arrived at the site of work.

Identification of causal factors

- 55 The RAIB has established that the LOWS equipment was working correctly, and that the absence of a warning from the equipment means that the lookout did not operate the warning activation switches. The Lookout was trained and had been passed competent as both a LOWS lookout and a LOWS controller in January 2011. He was an experienced LOWS user, who had not contributed to any previous safety related incidents, and he was aware of the approaching train (paragraph 41). The RAIB has concluded that the lookout had been aware of the train's approach and, based on witness evidence, that he believed he had given a warning. The investigation has therefore focused on why, in these circumstances, one or both of the following occurred:
- a. the Lookout mistakenly operated the operator vigilance switch instead of the warning activation switches (paragraph 58); and/or
 - b. the Lookout forgot about the need to send a warning after delaying his response because of the extended sighting distance available (paragraph 65 and figure 4).
- 56 For both of the above, vigilance degradation (refer to paragraph 72) may also have been a factor.
- 57 The investigation has also identified two underlying factors. These are:
- a. use of LOWS equipment, for which the human factors assessment did not encompass research which is now available; and
 - b. LOWS was vulnerable to a single point failure by one person.

These factors are now considered in turn.

Operator vigilance switch

58 It is possible that the Lookout operated the operator vigilance switch instead of the warning activation switches.

- 59 The Lookout had to operate the vigilance switch at least every 18 seconds to prevent an alarm sounding while the system was active. He often pre-empted the alarm by counting to himself so he could operate the switch before the alarm sounded. It is possible that the Lookout operated this vigilance switch, instead of the warning activation switches, because:
- there is a lack of distinctiveness between the two switch systems; and/or
 - he automatically repeated the behaviour pattern associated with the vigilance switch instead of operating the correct pair of switches.
- 60 The vigilance toggle switch is the same size and shape as the warning activation toggle switches (figure 6). The ZFH lookout unit emits similar tones for both the vigilance alarm and operation of the warning activation switches. These audible warnings are distinguished only by the vigilance alarm being a continuous tone and the warning activation being two short bleeps.
- 61 It is possible that one or both of these similarities increased the likelihood of a substitution error, in which the Lookout wrongly believed that he had operated the warning activation switches instead of the vigilance switch⁷. The RAIB notes that the risk of such an error could be reduced by increasing the distinctiveness of the respective switch designs and the difference in the feedback (audible tones) provided. Feedback would be further improved if the Lookout was able (and required) to check that his warning had been acknowledged at the site of work, but the RAIB acknowledges that achieving this is not possible with a uni-directional radio system such as that used in version 1 of the Zollner LOWS system (paragraph 17).
- 62 It is also possible that the Lookout incorrectly operated the vigilance switch because he responded to the train by automatically repeating an action he had carried out over 380 times in the 1 hour and 55 minutes since he had started acting as lookout. This highly practised activity increases the risk of habitual responding⁸. Vigilance degradation since the Lookout commenced his duty also increases the risk of an automatic action overriding the correct, but less practised, response⁹.
- 63 The risk of an automatic response was possibly increased unnecessarily because the requirement to acknowledge at intervals of about 20 seconds is significantly more frequent than required to maintain vigilance (refer to paragraph 74). By comparison, train driver vigilance systems generally require acknowledgements at intervals of no less than one minute. Zöllner UK has confirmed that the vigilance interval was not assessed when the ZFH unit was originally introduced to the UK from Germany, and that in Germany the interval was originally a lot longer. It is not known why the interval was reduced.

⁷ See eg, Norman, D.A. (1983). Design rules based on analyses of human error. *Communications of the ACM*, 26(4), 254-258.

⁸ Reason, J. (1990). *Human Error*. Cambridge: Cambridge University Press.

⁹ Fisk, A.D. and Schneider, W. (1981). Control and automatic processing during tasks requiring sustained attention: A new approach to vigilance. *Human Factors*, 23(6), 737-750.

64 There is evidence of previous incidents where a lookout is believed to have operated the vigilance switch instead of the warning activation switches in error and this risk is acknowledged in Zöllner UK's training materials (refer to paragraph 82).

Intended delay due to extended sighting distance

65 It is possible that the Lookout forgot about the need to send a warning after delaying his response because of the extended sighting distance available.

66 The RT9909 form completed by the COSS (paragraph 35) correctly identified that the lookout was required to give 25 seconds warning based on the nature of the work at site and the proximity of the workgroup's position of safety. This period included a 5 second allowance because LOWS was being used. The COSS used a *sighting distance chart* contained in the RT9909 form to calculate that the required sighting distance for a train approaching at the maximum permitted speed of 125 mph (201 km/h) was 1540 yards or 1400 metres (the form provides rounded values in both metric and imperial units). The Lookout's position close to Hest Bank level crossing was 770 metres north of the site of work, so to achieve the 1400 metres sighting distance required, the lookout needed to give a warning before a southbound train reached a point 630 metres north of his position, a distance that a train travelling at the maximum permitted speed would cover in 11 seconds.

67 In practice, the lookout could see the train much further away which introduced a risk presented by having an extended sighting distance. The section of the Railway Rule Book relating to site lookout duties¹⁰ states 'when you see a train approaching on the lines concerned ... you must immediately give the warning.' When he first saw a train it would have been more than 2.5 km away (paragraph 38), and over 3.2 km from the workgroup. If he gave the warning immediately, as required by the rule book, the workgroup would have received more than 57 seconds warning for a train approaching at 125 mph (201 km/h), more than 72 seconds warning for a train such as the incident train approaching at about 100 mph (161 km/h), and considerably longer for some other trains.

68 The Lookout informed the RAIB that he delayed giving a warning for up to 15 seconds after a train came into view. However, the long straight meant that, even with this delay, it was still a long time before the train passed him. He had not been briefed to delay the warning, but he was an experienced lookout and knew that this avoided giving the workgroup a warning considerably sooner than required for them to reach their position of safety. He judged this period by counting. This meant that, throughout this waiting period, the lookout had to remember that he needed to send a warning. In human factors terms, 'remembering to remember' is known as prospective memory.

69 Prospective memory for habitual tasks is dependent on having a cue to trigger the remembered action. The reliability of the intention being triggered is dependent on how prominent any trigger, such as the approaching train passing under a bridge, is. The Lookout was using counting as his cue and this provides a less prominent cue than a distinct event such as a train passing a landmark.

¹⁰ GE/RT8000/HB3 Rule Book, 'Handbook 3 Duties of the lookout and site warden'.

- 70 Prospective memory is also susceptible to interruption which in the context of this incident, could be operation of the vigilance switch or distraction (eg by road users at the level crossing). An interruption can result in a person forgetting to undertake the intended action, or strongly believing they have undertaken the action when they are actually recalling a generic memory of undertaking the action on a previous occasion, or recalling operating 'a switch' (ie the vigilance switch) thinking it was the warning switch (paragraph 61).
- 71 In some circumstances, individuals can rely on related cues rather than an actual event to trigger a response. The RAIB considered whether the Lookout was, perhaps unconsciously, relying on operation of the nearby level crossing as a cue to give a warning. The train service pattern meant that the barrier was sometimes lowered only for a northbound train, and was sometimes down for several minutes when trains passed in opposite directions. This would make barrier operation inconsistent with the need to give warnings for southbound trains. This, together with evidence from the Lookout, leads the RAIB to conclude that level crossing operation was not being used as a cue.

Maintaining Vigilance

72 It is probable that the Lookout's vigilance had degraded.

- 73 The role of a railway lookout requires sustained periods of vigilance. It involves monitoring an environment during periods of high and low levels of work activity. When the incident train approached, there had been a 26 minute interval since the previous train for which he had to give a warning. The Lookout was not required to give warnings for two northbound trains which had passed in this period.
- 74 The lookout's vigilance may have become degraded by one or more of the following:
- a. Time on task: the Lookout had been working continuously for nearly two hours. Human Factors research consistently demonstrates that vigilance for lookout-type actions can reduce significantly within 30 minutes (refer to paragraph 83).
 - b. Time of day (circadian rhythm): the incident occurred at a time when the Lookout was at risk of being affected by the 'post-lunch dip' in alertness¹¹.
 - c. Distraction: the Lookout was positioned facing Hest Bank level crossing and the associated public roads, and it is possible that the Lookout was distracted, perhaps only briefly, by activity at this location.
 - d. The lack of feedback from the ZFH lookout unit (paragraph 61).

¹¹ Wallace, J.C., Vodanovich, S.J. and Restino, B.M. (2003). Predicting Cognitive Failures from Boredom Proneness and Daytime Sleepiness Scores: an Investigation within Military and Undergraduate Samples. *Personality and Individual Differences*, 34. 635-644.

- 75 Following fatal accidents involving lookouts at Whitehall West junction, Leeds, in December 2009 (RAIB report 15/2010) and Newark in January 2014 (RAIB report 01/2015), Network Rail had given consideration to the effect of vigilance degradation on lookout performance. Its ergonomics team, which deals with human factors, concluded that lookouts should be allowed a minimum 5 - 10 minute break after not more than two hours, and have 'permission' to ask for a break. The ergonomics team has stated that this limit was based on "what we can do realistically, and what's manageable" after discussions with lookouts, but was not scientifically based. The RAIB notes that the period of two hours is considerably greater than can be justified by most research (refer to paragraph 83b).
- 76 The two hour limit had been incorporated into guidance given in COSS training, but it had not been made mandatory. The COSS was aware of this guidance, but he was focused on the track repair work and had made no plan to rest the lookouts during the session. On this occasion, although the session length was extended unexpectedly by failure of the ZPW control unit's battery (paragraph 39), it is probable that work would have still have continued for more than two hours without this interruption.
- 77 The RAIB has considered the Lookout's shift pattern, and concluded that this did not in itself create a fatigue risk as he worked six day shifts per week. Although he had been awake for about eight hours at the time of the incident, this is not associated with an increased risk of error.

Identification of underlying factors

Human factors

- 78 **It is possible that incorporating recent human factors research into the lookout's role would have avoided the incident.**
- 79 Network Rail introduced the Zöllner ZPW-LOWS in early 2008 after it had been approved for use by means of its Product Acceptance process. Zöllner UK's submission included an appraisal that focused on physical ergonomics of the unit commissioned from a UK ergonomics consultant, but did not assess the issues of the system in use. Network Rail's ergonomics team had no involvement in the introduction of this equipment, despite this being a requirement of Network Rail standards¹². This was possibly because of the work already done by Zöllner UK.
- 80 The appraisal specifically excluded an assessment of the ZFH lookout unit, other than considering its use with a new transmitter booster carried in a backpack. This was because Network Rail had already approved the ZFH device for use with an earlier system, the Zöllner Autoprowa Light (ZAL) track warning system in November 2003 which, in turn, was based on an existing accepted ATWS system.
- 81 The RAIB notes that the ZFH's design uses similar toggle switches and audible tones for both vigilance and warning activation, and also includes limited feedback to the operator. These features are inconsistent with good design practice relative to human factors (paragraph 61).

¹² Network Rail standard NR/SP/ERG/24020 (renumbered NR/L2/ERG/24020) 'Incorporating Ergonomics Within Engineering Design Projects: Requirements', Issue 2, April 2004.

- 82 The risks associated with the ZPW/ZFH device were recognised in Zöllner UK's training material which identified the following examples of lookout error among seven recurring causes of LOWS incidents based on operational experience:
- Lookout saw the train but did not send a warning;
 - Lookout was distracted and did not send a warning; and
 - Lookout operated vigilance switch to announce train.
- 83 Network Rail's ergonomics team commissioned a review of vigilance research from the University of Nottingham following the lookout fatality at Whitehall West Junction in December 2009. The Nottingham report, completed in 2011, identified that:
- a railway lookout is undertaking a vigilance task;
 - there is a significant loss of vigilance (decrement) within 30 minutes, according to most research, because vigilance tasks are resource demanding;
 - a minority subset of research suggests that, in certain contexts, significant decrement does not occur until after one hour;
 - a simple interruption such as a phone call can 'reset' vigilance;
 - a cue when to take action and system feedback can both reduce the vigilance decrement;
 - low frequency events can make detection of a target (ie a train) less efficient¹³; and
 - fatigue, which may be linked to factors such as circadian rhythms and time on task, can affect vigilance negatively.
- 84 Network Rail's ergonomics team produced a report summarising the findings of the Nottingham research in September 2011. This concluded that there were implications of this research that were applicable to lookouts using LOWS and their training. It also concluded that lookouts using LOWS were susceptible to reduced task engagement and thus reduced vigilance. This was because the lookout was physically isolated from the workgroup and received no feedback from the controller when a warning was given. It recommended that literature identified by the Nottingham report was reviewed by members of Network Rail's LOWS Steering Group to assess the implications particularly in relation to the design/upgrade of new systems. The ergonomics team had an input to the design of ZPW-LOWS version 1.5 equipment to improve feedback to the lookout (refer to paragraph 115).

¹³ Parasuraman, R. (1979). Memory load and event rate control sensitivity decrements in sustained attention. *Science*, 205(4409), 924-927.

- 85 An additional human factors issue relates to extended sighting distances, and the Lookout's practice of delaying the giving of a warning until a period of time after first seeing the train. This issue has been identified in a previous RAIB investigation and requires Network Rail to either:
- ensure compliance with the existing requirements which sometimes mean lookouts give warnings a significant time period before they are needed, a practice which could make it impossible to access the track in busy areas; or
 - introduce alternative requirements allowing lookouts to operate in a manner which means they do not give warnings significantly before they are needed.

The recommendation resulting from the previous RAIB investigation led to responses indicating that Network Rail was intending to implement the second of these options (refer to paragraph 98).

Single point failure

86 **LOWS was vulnerable to a single point failure by one person.**

- 87 The sighting distance available at the site of work was restricted to about 150 metres by the A5105 bridge. This meant that the workgroup had just over three seconds to clear the track after the train, travelling at 44 metres per second (98 mph, 158 km/h), came into sight. This made this incident a high risk event. There was no requirement for the LOWS Controller, or any other member of the workgroup, to maintain a look out for approaching trains. They were relying entirely on LOWS, a system often used in locations where sighting distances from the site of work are very short and train drivers will be unable to give effective warning using the train horn. This illustrates that reliance on current LOWS arrangements is vulnerable to the risk of a single point failure due to a lookout not giving a warning.
- 88 This incident is one of several similar lookout-related failures. Network Rail has provided information on 25 incidents involving LOWS version 1.4 equipment which occurred between May 2011 and September 2014 (excluding Hest Bank). This includes 10 incidents for which a lookout failing to send a warning is the known or probable cause.

Summary of principal cause (known or probable)	Number of incidents
Lookout error (eg distraction, vigilance, wrong switch)	10
Lookout in wrong position	3
Set-up error (including miscommunication between lookout and controller)	4
Controller error	4
Radio issues (repeated loss of contact, alleged interference between ZFH lookout units)	2
Cause not established	2

Table 1: Summary of data provided by Network Rail for previous similar incidents

- 89 In locations where a site lookout lacks the sighting distance required to give the required warning time, warnings can only be given by:
- a track or train operated system (ATWS or TOWS);
 - a lookout operated warning system (ie LOWS); or
 - a distant lookout to signal the approach of trains to the lookout at site¹⁴.
- 90 Where a distant lookout is provided, a site lookout is also required to watch for the warning flag and then to instruct workers to move to their position of safety. The site lookout will therefore see an approaching train and give a warning even if the distant lookout fails to warn of the approaching train. Although unlikely to provide the full required warning, this could be sufficient to prevent an accident. This second line of defence is not provided within existing LOWS procedures.
- 91 Although LOWS procedures lack the second line of defence provided by a site lookout, the LOWS system provides advantages over the use of unassisted lookouts. It reduces the number of people deployed close to the operational railway and gives a continuous visual and audible alarm until all staff are in a position of safety. The RAIB investigation has not included acquisition of the data needed to compare the relative safety of LOWS and lookouts equipped with flags. However, this report includes a recommendation that their relative positioning on the hierarchy of protection methods (paragraph 31 and appendix C) should be reviewed in the light of the events included in table 1.

Observations

System of work

92 **The safe system of work was not implemented in accordance with Network Rail processes.**

- 93 The investigation has identified the following non-compliances with Network Rail processes:
- The Safe System of Work pack had not been checked by a responsible manager, or reviewed by a more senior manager to permit its use on the same shift it was prepared (paragraph 30), and its late production meant that the COSS did not have adequate time to review the pack prior to work starting. As a consequence, some minor errors and omissions in the pack were not identified or corrected. RAIB reports into near-miss incidents involving track workers at Bridgeway in January 2014 ([RAIB report 25/2014](#)), and Roydon in July 2012 ([RAIB report 07/2013](#)) also identified this issue.
 - The lookout not involved in the incident (Lookout 2, paragraph 35) had not signed the COSS briefing sheet for the afternoon's task. The RAIB observes that he had signed the briefing sheet for the morning's task and had remained at the same location for the afternoon session, but facing in the opposite direction (paragraph 35). The importance of such briefings is stressed as the lack of an appropriate COSS briefing may have been a factor in the fatal accident involving a lookout at Newark in January 2014 ([RAIB report 01/2015](#) refers).

¹⁴ In some cases, an intermediate lookout can also be provided to relay warnings.

- Contrary to Network Rail's requirement, some of the track workers were not wearing hard hats at the time of the incident, but were reported to have done so earlier in the afternoon.

None of the above non-compliances had any influence on the incident and therefore were not investigated further by the RAIB. However, given the number of previous investigations in which such non-compliances have been discovered, the RAIB has written to Network Rail to express its concern at this further evidence that safety arrangements are often not being implemented as intended.

Train data

94 Data recorded by equipment on the incident train was not readily available to support the investigation.

- 95 FTPE did not download the OTDR immediately in response to the incident. Although it is FTPE's policy is to download data within 8 hours of an incident, it was not done on this occasion due to an oversight. FTPE staff subsequently undertook a routine download from the train's OTDR, but this covered several days of operation. The required information was not provided to the RAIB in a useable format until January 2015, four months after the incident.
- 96 When the OTDR was analysed by FTPE in January 2015, it was found that the operation of the train horn was not recorded. Investigation by FTPE showed that the horn input to the OTDR system had been isolated after an electrical circuit breaker was opened by the train's maintainer. Loss of the horn input was an unintended consequence of work intended to improve the operation of the train horn, and had affected all of the class 350/4 units operated by FTPE. The loss of horn input had not been detected by FTPE between the modification being undertaken in May 2014 and provision of OTDR data to the RAIB eight months later.
- 97 The CCTV recording provided to the RAIB had been copied to an 'avi' video format by FTPE. This recording played approximately 30% slower than real time, and the lack of an on-screen clock as part of the recording meant that this anomaly was not immediately obvious. In the absence of OTDR data (paragraph 95), reliance on video evidence meant that the RAIB's initial calculation of the train's speed (80 mph, 129 km/h) was incorrect. The issue only became apparent when the RAIB compared timings taken from the CCTV recording with signalling data and a statement given by the train driver to his employer. In other circumstances, the incorrect playback speed could have led to incorrect conclusions.

Previous RAIB recommendations relevant to this investigation

- 98 The following recommendation, which was made by the RAIB as a result of a previous investigation, has relevance to this investigation.

Track worker struck by a train at Cheshunt Junction, RAIB report 06/2011, Recommendation 2

The RAIB considers that full implementation of Recommendation 2 in report 06/2011 could have addressed the issue of extended warning times (due to extended sighting distances) which was an issue identified in both the Hest Bank investigation and (although LOWS was not being used) in the Cheshunt Junction investigation. The recommendation reads as follows:

Recommendation 2

Network Rail should evaluate the behaviour of staff working on the track at locations with extended sighting times. The objective of this evaluation shall be:

- a. to understand the methods adopted by track workers at such locations;*
- b. to assess the risk introduced by extended warning times;*
- c. to assess the risk introduced by any alternative working practices that may be identified by staff; and*
- d. to consider the need for additional guidance to the COSS and other safety critical staff.*

Based on its understanding of current behaviour gained from this evaluation, Network Rail should establish a safe system of work to cover activities at locations with extended sighting times.

- 99 Network Rail's internal review of this recommendation was signed off on 15 October 2012 with the following conclusion:

'There is an outstanding action to formalise the practice of using trigger points. A Rule Book change proposal has been submitted and a proposal put forwards for changes to be made to COSS training. Progress with both has been delayed due to the current standards moratorium and the revisions to the COSS NTS [non-technical skills] programme. The Head of Workforce Safety is in the lead for ensuring that the actions are implemented.'

- 100 On 27 February 2013, the ORR wrote to RAIB stating that this recommendation had been 'implemented by alternative means'. ORR's letter stated:

'ORR is content with the Network Rail's actions and will check that lookouts are now adequately aware of the need for suitable trigger points for long sighting distances and the risk effectively managed. If, in doing so, we become aware of an inaccuracy in what we have reported we will write to RAIB again.'

101 After being contacted by RAIB in connection with the Hest Bank investigation, Network Rail's action tracking team confirmed that a proposal consistent with the ORR's letter had been put together but did not get submitted to the relevant committee. On 6 February 2015, Network Rail stated:

'Cheshunt Recommendation 2 will be re-opened by Network Rail's recommendation team, and will remain open and tracked until all these outstanding actions have been completed.'

Network Rail has subsequently requested clarification from the RSSB in relation to trigger points and the interpretation of the rule. Once this is clarified, Network Rail will expand the training material relating to trigger points and will issue this in June 2015.'

102 On 1 April 2015, the ORR formally reclassified the status of this recommendation to 'In Progress' and has stated that it will follow up accordingly.

103 The RAIB considers that implementation of Cheshunt Junction Recommendation 2 had the potential to reduce the risk associated with the lookout delaying his warning because of the extended warning times (due to extended sighting distances).

Summary of conclusions

Immediate cause

104 The workgroup did not receive a warning of the train before it arrived at the site of work (paragraph 54).

Causal factors

105 The incident occurred due to a combination of the following causal factors:

- a. It is possible that the Lookout operated the operator vigilance switch instead of the warning activation switches (paragraph 58; no recommendation due to action taken, paragraph 116).
- b. It is possible that the Lookout forgot about the need to send a warning after delaying his response because of the extended sighting distance available (paragraphs 65 and 103; no recommendation due to action taken, paragraph 120).
- c. It is probable that the Lookout's vigilance had degraded (paragraph 72, **Recommendation 1**).

Underlying factors

106 The underlying factors were:

- a. It is possible that incorporating recent human factors research into the lookout's role would have avoided the incident (paragraph 78, **Recommendation 2**).
- b. LOWS was vulnerable to a single point failure by one person (paragraph 86, **Recommendation 2**).

Observations

107 The safe system of work was not implemented in accordance with Network Rail processes (paragraph 92).

108 Data recorded by equipment on the incident train was not readily available to support the investigation (paragraph 94; no recommendation due to actions taken, paragraph 122).

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

109 It is possible that the Hest Bank incident would have been avoided by implementation of a recommendation relating to managing extended warning times due to extended sighting distances, made by the RAIB in 2011 following an investigation into an accident at Cheshunt Junction (paragraphs 98 to 103).

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

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

- 110 Following this incident, Network Rail's Lancashire & Cumbria delivery unit has:
- prohibited further use of LOWS version 1.4 equipment; and
 - trials ZPW-LOWS version 1.5 equipment which gives improved user-feedback and has the vigilance switch replaced by a movement sensor (refer to paragraph 115).
- 111 Network Rail has also introduced 'non-technical skills' training for lookouts as an e-learning course in July 2014, with a requirement for all lookouts to complete it by July 2015 in order to maintain their competence. The training includes modules on 'attention management', which cover the ability to remain alert and focussed, the ability to manage distractions, and the ability to keep an awareness of the overall situation. The training includes scenario-based discussions. The training mentions the 30-minute vigilance degradation, but other areas of the training advise lookouts to ask for breaks every 1.5 hours and if they are aware their vigilance is degrading. The RAIB notes that this is inconsistent with the two hour interval suggested by Network Rail's ergonomics team and included in COSS training (paragraphs 75 and 76). It is also inconsistent with the 30 minute period over which significant vigilance degradation will occur according to most research (paragraph 83b).
- 112 The RAIB has concluded, on the basis of existing research, that vigilance degradation is a 'hard-wired' part of the human condition¹⁵ and is not a 'skill' that can be trained because:
- all individuals are susceptible; and
 - self-monitoring for vigilance degradation is unreliable¹⁶.
- 113 Although training is useful to raise awareness of these risks, it is unlikely to mitigate such risks completely. This means that the vigilance problem is best addressed through design of the task or equipment; issues addressed by the recommendations in this report.
- 114 The Zöllner LOWS version 1.4 product acceptance certificate is due to expire in April 2016. Routes intending to use Zöllner LOWS equipment after this date must upgrade to the version 1.5 or version 2 equipment described below.

Zöllner LOWS version 1.5 equipment

- 115 An upgrade to the LOWS ZFH lookout operated transmitter units was developed with input from Network Rail's human factors specialists. The new system, known as version 1.5, obtained full product approval for use on Network Rail infrastructure in August 2014. Trials have been ongoing since that date and the upgrading of existing equipment has commenced.

¹⁵ Wickens, C. D., Lee, J. D., Liu, Y. & Gordon-Becker, S. (2003). An Introduction to Human Factors Engineering (2nd Edition). Pearson.

¹⁶ Mackie, R. (1977). Vigilance: Theory, Operational Performance, and Physiological Correlates. New York: Plenum.

- 116 The version 1.5 ZFH lookout operated transmitter unit includes the following modifications (figure 11):
- a. removal of the vigilance switch and replacement by a motion sensor which detects whether the lookout stops moving;
 - b. provision of an LED indicator which displays for 10 seconds to confirm to a lookout that a warning has been given; and
 - c. provision of a data logger function.



Figure 11: ZFH version 1.4 lookout unit (left) and ZFH version 1.5 lookout unit (right); note absence of vigilance switch on version 1.5 unit

117 Network Rail has conducted trials using Zöllner LOWS equipment connected to one or more *treadles* to detect the wheels of passing trains. This system automatically detects an approaching train (automatic strike-in), but requires the warning to be cancelled manually after the train has passed (manual strike-out). It is referred to as a semi-automatic track warning system (SATWS), effectively ‘portable TOWS’ (**Recommendation 2**).

Zöllner LOWS version 2 equipment

118 LOWS version 2 equipment obtained full product approval for use on Network Rail infrastructure in November 2014. It has been trialled, and Network Rail intends that version 2 equipment will be obtained when there is a need to purchase additional sets.

119 LOWS version 2 equipment has a bi-directional radio link between the ZFS radio transmitter and the ZPW control unit (figure 12). The message 'Control Unit in Warning Mode' is displayed to the lookout until the warning is acknowledged by the LOWS controller at the control unit on site. Most Zöllner LOWS equipment in use outside the UK is already version 2. Version 2 equipment is suitable for use with treadles or axle counters.



Figure 12: Zöllner LOWS version 2 ZFS radio transmitter and ZPW control unit

RAIB Cheshunt Junction report

120 Network Rail and the ORR have re-opened recommendation 2 from the RAIB's Cheshunt Junction report (paragraphs 101 and 102). The intent of this recommendation is to assist staff to establish a safe system of work to cover activities at locations with extended sighting distances.

Recommendations management

121 Network Rail modified its recommendation handling process in October 2014 because it recognised the previous process required improvement. This involved a revision to its Investigations Handbook¹⁷ which now states:

'Recommendations are made to improve our safety performance so should only be closed when either:

- a) the risk that the recommendation seeks to address has been eliminated; or*
- b) improved risk mitigation has been implemented.*

When considering if the above have been achieved the wording of the recommendation and its intent should be considered.'

All closure statements are now subject to an independent review by Network Rail's Corporate Investigation and Assurance Manager to check that they meet the criteria above.

¹⁷ Part 10 – Recommendation Owners' Guidance.

Other reported actions

122 FTPE, in response to this incident and subsequent RAIB enquiries, is taking action to:

- a. re-brief relevant staff on its policy for capturing OTDR data following reported incidents (paragraph 95);
- b. reinstate the horn input to OTDR for class 350/4 units (paragraph 96); and
- c. discontinue providing CCTV recordings in non-original file format to ensure that recordings can be viewed at the correct speed (paragraph 97).

Recommendations

123 The following recommendations are made¹⁸:

- 1 *The intent of this recommendation is to promote a review of working time limits that is consistent with current human factors research.*

Network Rail should reassess the working time limits and duration of breaks applicable to lookouts and provide staff with appropriately updated instructions and guidance based on these findings. This reassessment should make use of current research into vigilance activities akin to railway lookout duties (paragraph 105c).

- 2 *The intent of this recommendation is to ensure that LOWS is appropriately positioned within the safe system of work hierarchy, taking account of engineered solutions available to mitigate the risk of a single point of failure due to complete reliance on the action of one lookout.*

Network Rail should reassess the safe system of work hierarchy, taking account of evidence from LOWS related incidents and the risk associated with using unassisted (flag) lookouts. If justified by the results of current tests of Semi-Automatic Track Warning Systems, where workforce warnings are initiated using automatic train detection, Network Rail should include such equipment within the hierarchy. If appropriate, Network Rail should specify any circumstances in which this should be used in preference to LOWS (paragraphs 106a, 106b and 117).

¹⁸ 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.gov.uk/raib.

Appendices

Appendix A - Glossary of abbreviations and acronyms

ATWS	Automatic Track Warning System
CCTV	Closed-circuit television
COSS	Controller of site safety
FTPE	First TransPennine Express
LED	Light emitting diode
LOWS	Lookout operated warning system
NMT	New measurement train
ORR	Office of Rail Regulation (now known as Office of Rail and Road)
OTDR	On-train data recorder
RSSB	Rail Safety and Standards Board
SATWS	Semi-automatic track warning system
SSoW	Safe system of work
TOWS	Train operated warning system
ZFH	Zöllner ZFH lookout operated transmitter unit
ZPW	Zöllner ZPW control and warning unit

Appendix B - Glossary of terms

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

Automatic Track Warning System	An automatic system of warning track workers when a train is approaching.
Limited clearance	An area where there is insufficient space to stand safely during the passage of trains on the adjacent line.*
Line blockage	An arrangement where a section of line has no train movements and is safeguarded.
Measured shovel packing	A manual technique for accurately addressing small vertical errors in the track. The lift required is measured, and an appropriate number of cans of chippings are introduced under the sleeper to achieve this lift.*
New Measurement Train	A geometry and track recording train, largely based on existing High Speed Train (HST) vehicles. This formation can record cant, crosslevel and gauge at speeds of up to 125 mph.*
Position of safety	A minimum of 2 metres (6 feet 6 inches) from a line on which a train can approach at over 100 mph. Rule Book Handbook 1 (GE/RT8000/HB1) refers.
Possession	A line is under possession when arrangements have been carried out to block the line completely to the normal passage of trains in accordance with the Rule Book GE/RT8000 so that engineering trains or on track plant can be used.
Responsible manager	The person responsible for the management of staff who will work on or near the line.
Safe system of work pack	A pack of information used by the COSS/IWA that provides details of the site of work, the work to be done and the suggested Safe System of Work in accordance with Network Rail standard NR/L2/OHS/019 and the Rule Book GE/RT8000.
Sighting distance	The distance at which trains must be seen in order to give adequate warning time.
Sighting distance chart	Chart contained within certain handbooks of the railway rule book, and on form RT9909, which allows the calculation of the required sighting distance for a safe system of work, based on the maximum permitted speed of trains and the required warning time.
Track gauge	A device for measuring gauge (distance between the rails) and cant (height difference between rails).
Train Operated Warning System	A system operated by trains used for warning track workers when a train is approaching.

Treadle	A mechanical arm attached to the side of the rail which is operated by the wheels of a passing train.
Twist fault	A rapid change in cant or crosslevel.*
Underbridge	A bridge spanning an opening under a railway.
Up line	Line on which the normal direction of trains is towards London.
Warning time	The amount of time needed to ensure everyone is in a position of safety at least 10 seconds before the arrival of an approaching train.
Workgroup	Staff whose safety is managed by a Controller of Site Safety (COSS).*

Appendix C - Hierarchy of Safe Systems of Work defined in Network Rail standard NR/L2/OHS/019, Issue 8, 4 September 2010

1	<p>Safeguarded Green Zone, unless:</p> <ul style="list-style-type: none"> • the required blockage(s) of the line(s) are not available or • the time required to take the line blockage is disproportionate.
2	<p>Fenced Green Zone, unless:</p> <ul style="list-style-type: none"> • the required blockage(s) of the line(s) are not available or • the time required to erect and dismantle fencing is disproportionate.
3	<p>Separated Green Zone, unless:</p> <ul style="list-style-type: none"> • the required blockage(s) of the line(s) are not available or • the time required to set up a separated Green Zone is disproportionate.
4	<p>Red Zone with warning given by Automatic Track Warning System (ATWS), unless:</p> <ul style="list-style-type: none"> • the time required to plan, install and remove ATWS is disproportionate or • the required equipment is not available or • the equipment is not suitable for the location (see NOTE 7 below).
5	<p>Red Zone with warning given by Train Operated Warning System (TOWS), supplemented where necessary by other methods of warning, unless:</p> <ul style="list-style-type: none"> • TOWS is not available at the location or does not provide an adequate warning for the work.
6	<p>Red Zone with warning given by Lookout Operated Warning System (LOWS), unless:</p> <ul style="list-style-type: none"> • the time required to plan, install and remove LOWS is disproportionate or • the required equipment is not available.
7	<p>Red Zone with warning given by one or more Lookouts or COSS/IWA working alone and looking out for him/herself.</p> <p>THIS SHALL ALWAYS BE REGARDED AS THE LAST RESORT.</p>

NOTE 7 - ATWS guidance

The required equipment may be unsuitable for the location if:

- *the track layout is complex, involving multiple lines, junctions, crossovers etc.;*
- *trains normally stop at a point between the strike in point and the site of work; and/or*
- *radio based ATWS is intended to be used in an area of radio interference.*

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