Rail Accident Investigation Branch

# Rail Accident Report

## Derailment in Summit tunnel, near Todmorden, West Yorkshire
## 28 December 2010

Department for Transport

Report 16/2011
September 2011

This investigation was carried out in accordance with:

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



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# Derailment in Summit tunnel, near Todmorden, West Yorkshire, 28 December 2010

## Contents

# Summary


In the early hours of 28 December 2010, a passenger train was travelling from Manchester to Leeds when it struck a large amount of ice that had fallen onto the tracks from a ventilation shaft in Summit tunnel. All wheels of the front bogie were derailed to the left in the direction of travel causing the front driving cab of the train to strike the tunnel wall. The train remained upright and once it had stopped, the train crew took action to protect the train and raise the alarm. About three hours later, the passengers and train crew had been led out of the tunnel by the emergency services. No injuries were reported, while the train suffered damage to its cab windscreen, a coupler, bodywork and underframe. There was minor damage to the track.

The ice formed as water, seeping through the lining of a ventilation shaft, froze during a long period of freezing temperatures. This ice fell onto the track after a thaw which started on 27 December 2010. The train, which was the first to pass through the tunnel in over 3 days due to the Christmas holiday period, then collided with it. A combination of factors led to this accident:

- the risk of ice, particularly ice falls onto the track, was not identified before the train service resumed so the train was allowed to enter Summit tunnel while running at its maximum permitted speed; and
- the routine maintenance regime did not identify excessive ice in the tunnel and no additional inspections were carried out.

The RAIB has made five recommendations, all directed to Network Rail. The first recommendation relates to how water in Summit tunnel is managed. The second is about identifying those structures which are at risk from extreme weather and then checking they are safe to use after periods when no trains have been running. The third calls for the potential hazards due to extreme weather and thaw conditions to be taken into account in Network Rail's weather management processes. The fourth calls for training and information to be given to staff who need to carry out the additional inspection of structures that are at risk in extreme cold weather. The fifth relates to the management of safety related information (and details of actions taken) that is passed from Network Rail's buildings and civils – asset management function to other parts of the company.

# Preface

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

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

# Key Definitions

3 All dimensions and speeds in this report are given in metric units, except speeds and locations on Network Rail, which are given in imperial dimensions, in accordance with normal railway practice. In this case the equivalent metric value is also given.

4 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.

5 References made to left and right are as viewed facing forwards in the direction of travel of the train involved in the accident.

# The accident

## Summary of the accident

6 At about 01:23 hrs on 28 December 2010, a passenger train travelling through Summit tunnel (figure 1) derailed while travelling at 57 mph (92 km/h) when it struck a large amount of ice that had fallen onto the tracks underneath one of the tunnel's ventilation shafts. All wheels of the front *bogie* of the train were derailed to the left in the direction of travel, causing the front driving cab of the train to strike the tunnel wall.


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

7 During the immediate aftermath of the derailment there were further falls of ice onto the roof of the derailed train, which caused alarm among the passengers. By 04:40 hrs, the 45 passengers and 2 train crew had been evacuated from the train and led out of the tunnel by the emergency services. None of the passengers or train crew were injured. However, the train's driver was badly shaken.

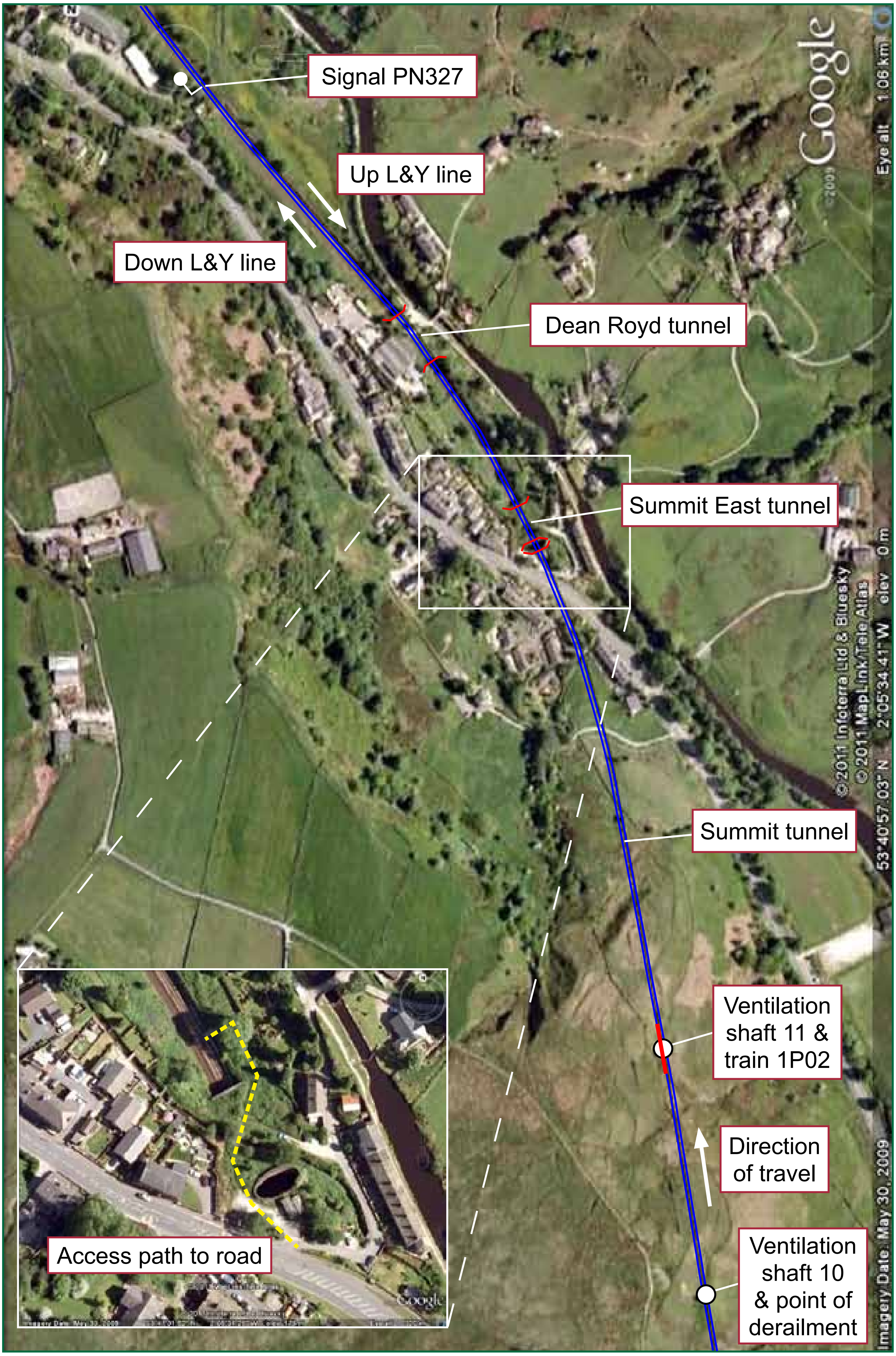


*Figure 2: Overview of accident site showing geographical relationship of key features (courtesy of Google Earth)*

8 The train suffered damage to the front end and left side of the leading vehicle. There was also minor damage to the track. The tunnel lining remained intact.

9 The railway line through the tunnel remained closed until 23:00 hrs on 28 December 2010 while the train was recovered, the track damage assessed, and the ice and icicles removed.

## Organisations involved

10 Network Rail owns, operates and maintains the infrastructure which includes the track and the tunnel. Network Rail staff examine the track and Amey staff are contracted to examine Network Rail's structures, including tunnels, as part of a national agreement.

11 The train was operated by First TransPennine Express, who also employed the driver and conductor.

12 Network Rail, First TransPennine Express and Amey freely co-operated with the investigation.

## Location

13 Summit tunnel is located beneath the Pennines between Littleborough and Walsden stations on the railway line that runs between Manchester and Leeds, via Hebden Bridge (figures 2 and 3). It is 1 mile 1125 yards (2.638 km) long, with the Littleborough end portal located at 15 miles 13 *chains* and the Walsden end portal located at 16 miles 64 chains, both from a zero reference at Manchester Victoria station. It lies on an approximate north to south axis and spans the boundary between Greater Manchester and West Yorkshire.

14 The tunnel was constructed between 1838 and 1841 by the Manchester and Leeds Railway and was the longest railway tunnel in the world when it opened. The tunnel bore is horseshoe shaped and is primarily brick lined although some areas are now lined with concrete after being repaired over the years. The tunnel was aligned and built by digging 14 construction shafts, which were to be used as ventilation shafts once the tunnel was in operation. Three of these shafts were closed during or just after construction and a further two shafts were closed during repairs after a major fire in 1984[1], leaving nine open shafts (figure 4).

15 The railway through the tunnel consists of a double track main line. The track consists of *continuous welded rail* on wooden *sleepers*. Signalling in the area is controlled from Preston *power signal box*. The train was travelling on the *Down* L & Y line which has a *permitted speed* of 70 mph (113 km/h), reducing in the tunnel to 65 mph (105 km/h) at 16 miles 40 chains (figure 3). There are no steep gradients in the tunnel. The RAIB has found no evidence that the condition or maintenance of the track contributed to the accident.

[1] On 20 December 1984 a freight train conveying loaded petrol tank wagons derailed and caught fire as it passed through Summit tunnel. For further details see Department for Transport report 'Report on the Derailment and Fire that occurred on 20th December 1984 at Summit Tunnel', dated 4th June 1986.

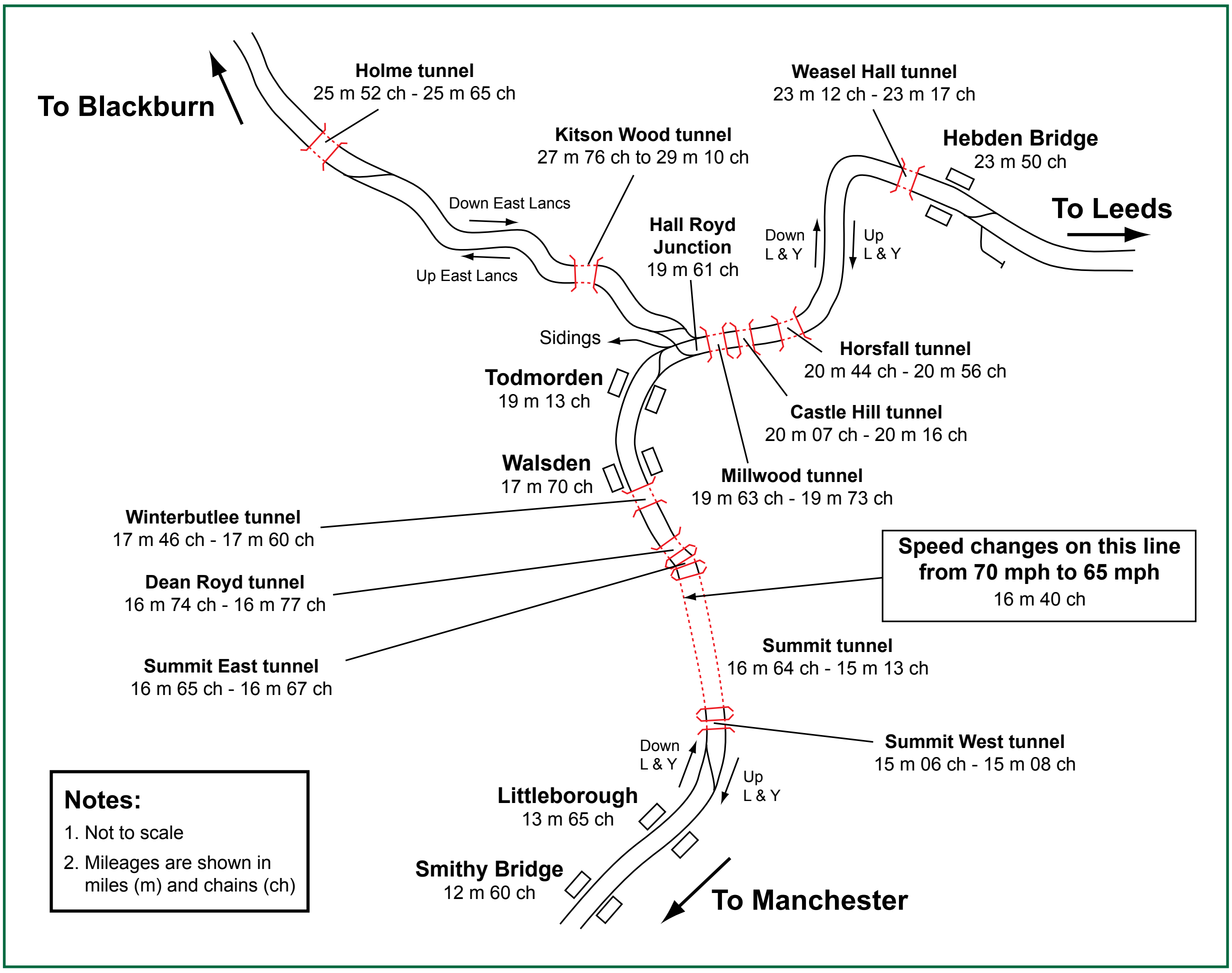


*Figure 3: Track layout, stations and other tunnels in the vicinity of Summit tunnel*

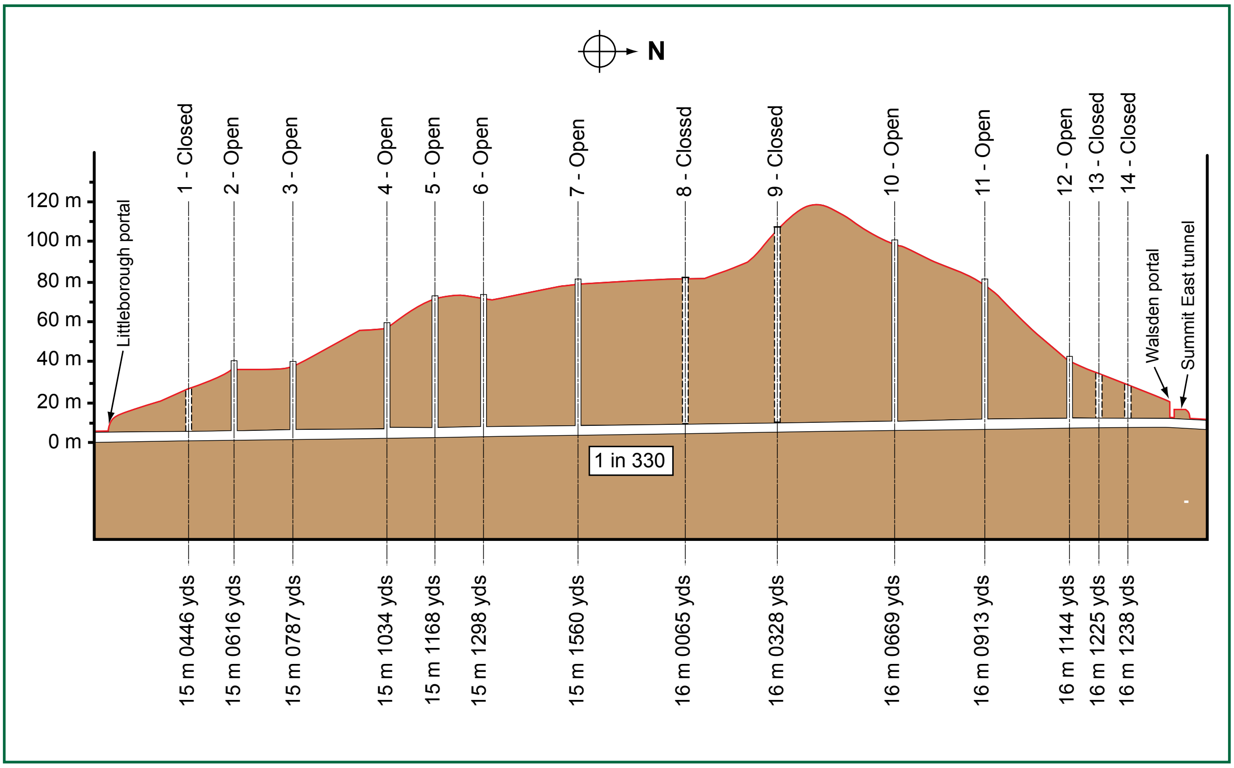


*Figure 4: Profile of Summit tunnel showing the location, depth and type of each shaft*

## External circumstances

16 The local weather conditions that night were cold, with a mix of clear spells and intermittent rain or sleet showers in places. However, the temperature remained above freezing. At the time of the accident, the temperature in the vicinity of Summit tunnel was 2°C.

## Train involved

17 The train involved was train 1P02, the 00:38 hrs service from Manchester Airport to York, which was running on time. The train consisted of a three car *diesel multiple unit*, class 185 unit number 185144. The RAIB has found no evidence that the operation, condition or maintenance of the train contributed to the accident.

18 There were no other trains running in the area at the time. There had been no trains through the tunnel in either direction since about 21:45 hrs on 24 December 2010 (paragraphs 24 and 25).

## Staff involved

19 The driver of train 1P02 was based at the First TransPennine Express train crew depot at York. He had 20 years experience of driving and was very familiar with the route and this type of train. The driver had not been involved in any similar accidents or incidents during his career. However, he had seen ice in tunnels on many occasions during winter months, with icicles brushing the roof of his train but not causing any damage to it.

20 The conductor of train 1P02 was also based at the First TransPennine Express train crew depot at York. He had been working in this role for eight years and had not been involved in any similar accidents or incidents during this time.

## Events preceding the accident

21 Figure 5 shows the ambient air temperature in the vicinity of Summit tunnel from mid-November 2010 to the time of the accident. A period of sustained cold weather started towards the end of November, with heavy snow falls and temperatures that were regularly below freezing. On 9 December, a thaw set in with ambient temperatures above freezing for the next seven days. On 16 December, the ambient air temperature again fell below freezing and stayed at or below 0°C throughout the next eleven days.

22 During this second spell of freezing temperatures, trains continued to run through Summit tunnel and no drivers reported problems with ice or icicles. On 19 December, Network Rail infrastructure maintenance staff walked through the tunnel while carrying out a *basic visual track inspection (patrol)*. They did not mention ice or icicles in their inspection report (see paragraph 76).

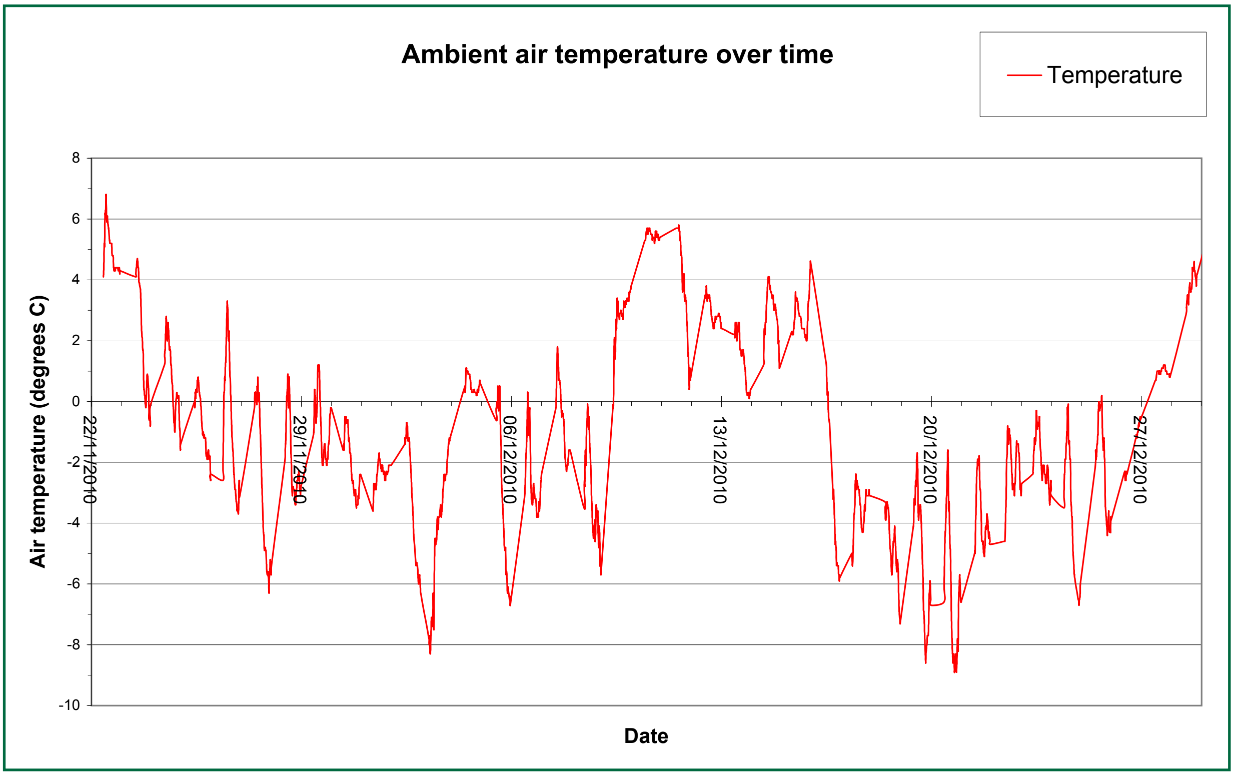


*Figure 5: Graph showing changes in ambient air temperature over time in the vicinity of Summit tunnel*

23 On 21 December, the assistant track maintenance engineer for the Blackburn area carried out an inspection of the line from Smithy Bridge to Hebden Bridge (figure 3) from the cab of a train, during which he passed through the tunnel (see paragraph 78). In his inspection report he noted that there were large icicles within Summit and several other tunnels. However, he did not consider them to be a risk to trains.

24 At about 21:45 hrs on 24 December, the last train before the Christmas holidays passed through Summit tunnel without incident. No trains were timetabled to run through the tunnel on 25 or 26 December and there was no engineering work taking place in or near the tunnel.

25 At about 01:00 hrs on 27 December, the ambient temperature in the vicinity of the tunnel rose above freezing and a thaw started. That day only Northern Rail services were planned to run through the tunnel but they were all cancelled due to industrial action. At sometime between the thaw starting and train 1P02 passing through the tunnel, a large amount of ice fell from ventilation shaft 10 onto the tracks below.

26 At about 19:45 hrs, both the driver and conductor booked on duty in York. They crewed a train from York to Manchester Airport via Huddersfield and then back to Manchester Piccadilly where they had a rest break. They then crewed a train to Manchester Airport which later formed train 1P02 to York via Hebden Bridge. Train 1P02 departed from Manchester Airport on time at 00:38 hrs and picked up further passengers at Manchester Piccadilly. It continued to Salford Crescent, where it reversed and then departed towards Summit tunnel.

## Events during the accident

27 Train 1P02 passed green signals on the approach to Summit tunnel and entered the Littleborough portal at about 01:22 hrs travelling at the permitted line speed of 70 mph (113 km/h). About 40 seconds later, the driver made a short brake application for 4 seconds to reduce the train's speed before the change in permitted speed to 65 mph (105 km/h). The train then coasted for the next 13 seconds and its speed fell to 62 mph (100 km/h). At this point the driver saw the ice piled up on the track about 150 metres[2] ahead of him and applied the train's *full service brake* at 01:23:16 hrs.

28 About four seconds later, the train struck the pile of ice while travelling at 57 mph (92 km/h). Upon impact, all wheels on the front bogie of the leading vehicle lifted and landed about nine metres further on, to the left of the running rails. None of the other wheels on the train derailed.

29 About four seconds after impact, the driver applied the train's *emergency brakes*. The train ran derailed for 254 metres, with the front left hand side of the train striking the tunnel wall in several places, before coming to a stop under ventilation shaft 11 (figure 6). The train remained coupled and upright, and it did not foul the adjacent line.


*Figure 6: Train 1P02 after it had stopped (courtesy of British Transport Police)*

[2] The RAIB estimated this distance using information recorded by the train's *on-train data recorder* and included a reaction time for the time it took the driver to apply the brakes after first seeing the ice.

## Events following the accident

30 Once the train had stopped the conductor tried to speak to the driver using the train's cab to cab intercom but got no answer, so he went to the front cab. He found the driver standing in the cab. The driver had not heard the intercom because there were many alarms sounding in the driving cab as a consequence of the impact damage sustained by the front *autocoupler*.

31 The driver and conductor agreed what they would do next. The driver turned off the train's engines and switched its headlights to give a flashing hazard warning indication. He also pressed the *emergency call* button on the train's radio, but found that there was no signal. The driver estimated that the train had stopped about a quarter of a mile from the portal at the Walsden end of the tunnel, so he set off in that direction to go to the nearest signal fitted with a telephone, which was outside the tunnel. At this time the conductor got off the train and placed *track circuit operating clips* on both lines. The conductor was concerned about the driver's welfare, but he got back on the train, and went through it to check that the passengers were all right and to let them know what was happening.

32 When the conductor put a track circuit operating clip on the line adjacent to the train, it worked correctly and caused the signal on the *Up* L & Y line outside the tunnel to go to danger, and the relevant *track circuit* to show 'occupied' on the signaller's *panel* in Preston signal box, at about 01:27 hrs. Realising that something was wrong, the signaller took action to stop any trains from approaching the tunnel, from both directions. The signal box shift manager also asked Network Rail control to make an emergency call to train 1P02. This was done but the call was not received; this was because there was no radio reception in the tunnel.

33 At about 01:35 hrs, the driver reached the first signal outside the tunnel, which was signal PN327 on the Down L & Y line. He used the telephone at the signal to make an emergency call to the signaller. The driver reported what had happened and asked for all of the emergency services to attend. The signaller confirmed to the driver that his train was protected, and after establishing some further details such as the location of the train, the emergency services were called and given the location of the nearest access point. Network Rail control was advised and they began mobilising Network Rail staff to go to the Walsden end of the tunnel. They also told First TransPennine Express control about the accident.

34 At 02:02 hrs the first tender from the West Yorkshire Fire Service arrived at the access point near the Walsden portal of the tunnel and at about 02:09 hrs, a Network Rail mobile operations manager arrived and met the driver who was waiting by the signal. By 02:13 hrs, all of the emergency services had arrived on site. The Network Rail mobile operations manager and emergency services then went with the driver back to the train, where they found out from the conductor that there were no passenger injuries.

35 The West Yorkshire Fire Service began preparing for the evacuation of the passengers by setting up lighting within the train and tunnel and identifying a safe path for the passengers to follow. First TransPennine Express arranged for a coach to collect the passengers which arrived at Walsden station at 03:30 hrs. At about 03:45 hrs, just before the evacuation was about to start, ice fell from ventilation shaft 11 onto the roof of the second vehicle. As a precaution, the fire service moved everyone into the leading vehicle and delayed the evacuation while they removed ice hanging from the tunnel roof above the planned evacuation path. Once this was done, the passenger evacuation began at 04:10 hrs and was completed by 04:40 hrs.

36 Afterwards, the passengers were assessed by paramedics before continuing their journey by road. One elderly passenger complained of chest pains and was taken to a local hospital in Todmorden as a precaution but was quickly discharged. The train crew were taken back to York by staff from First TransPennine Express who had been called to site.

37 The train's leading bogie was re-railed later that day, and after being inspected by First TransPennine Express staff, the train was moved under its own power at a maximum speed of 40 mph (64 km/h) back to Ardwick depot in Manchester.

38 Network Rail infrastructure maintenance staff assessed the damage to the track and used a *road-rail excavator* to knock down some of the ice still hanging from ventilation shafts 10 and 11. The excavator, with a trailer attached, was then used to remove the fallen ice from the tunnel. The railway line was reopened at 23:00 hrs that day, with a speed restriction imposed on the down line due to the damage to the track.

# The Investigation

## Sources of evidence

39 The following sources of evidence were used:

- interviews and staff reports;
- Network Rail's and First TransPennine Express's control logs;
- data from the train's on-train data recorder;
- site inspection photographs and measurements;
- weather reports;
- records held by Network Rail's asset management and infrastructure maintenance functions;
- Network Rail operations weather management documentation;
- Network Rail's company standards; and
- a review of previous RAIB investigations that had relevance to this accident.

# Key facts and analysis

## Background information

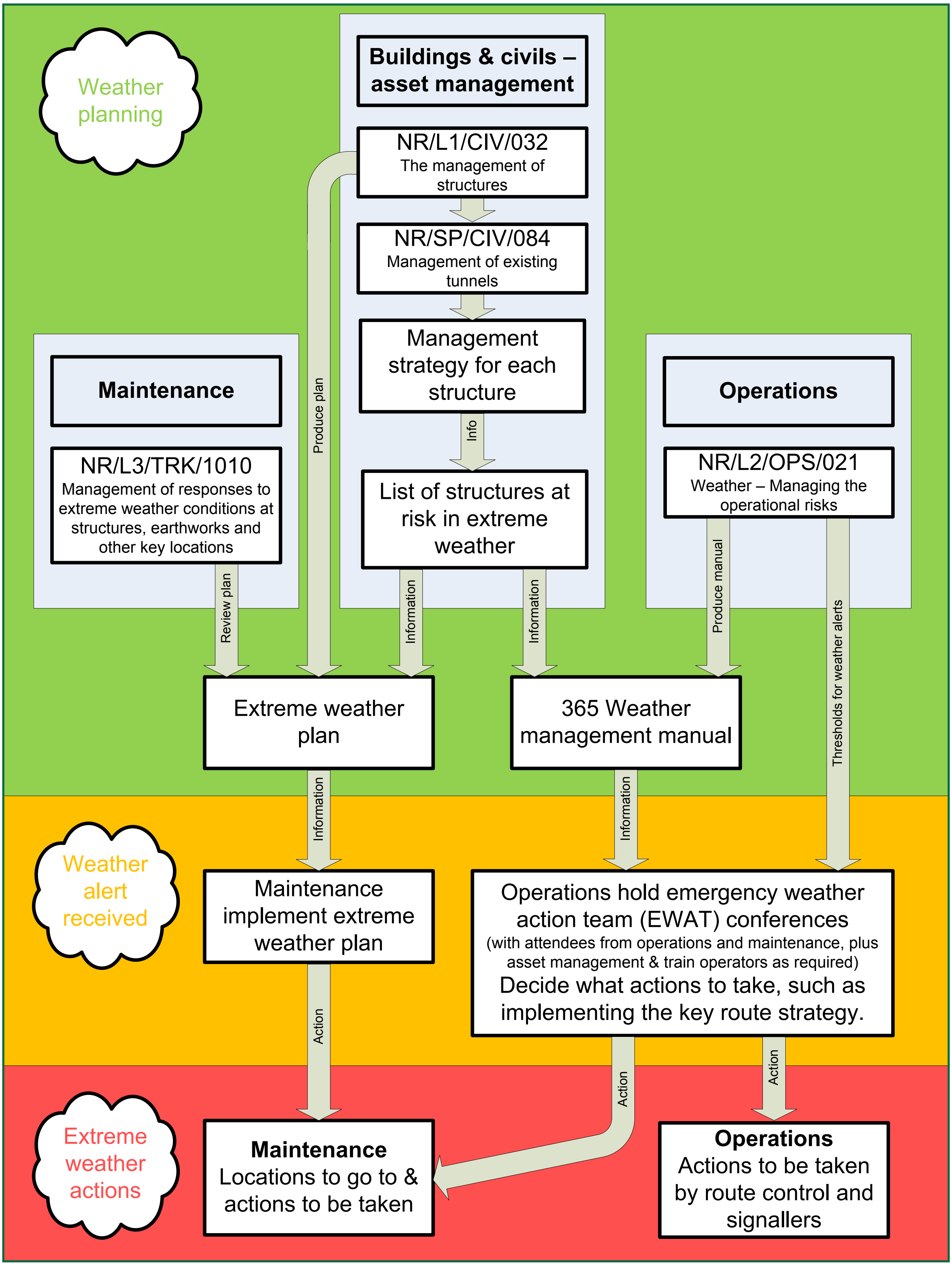


*Figure 7: Diagram showing the Network Rail company standards and the processes that should be followed for managing the risks to structures arising from extreme weather*

## Network Rail Buildings & Civils – Asset Management

40 Within Network Rail's buildings & civils – asset management function, a route structures engineer heads a group of structures engineers who manage about 17,000 structures[3] on Network Rail's London North Western (LNW) route. The group is split into four teams, with each team headed by a senior structures management engineer, who has two structures management engineers and two assistant structures management engineers reporting to them. Each team is responsible for managing a portfolio of structures on the route.

41 They arrange for their structures to be examined at the prescribed frequencies, as required by Network Rail company standard NR/L3/CIV/006/1C, 'Handbook for the examination of Structures Part 1C - Risk categories and examination intervals'. For tunnels, the bore must have a detailed examination every year and its shafts must have a detailed examination every six years, with annual visual examinations in between. These examinations are carried out by Amey under a national contract: the Civils Examination Framework Agreement (CEFA) contract. Amey documents what has been found during an examination in a report which is then submitted to Network Rail. The report includes recommendations on what work is needed, with each defect found given a risk score. The structures management engineers then review these reports and decide what repair work needs to be carried out. Network Rail manages these activities using their 'Civil Asset Register and electronic Reporting System' database (CARRS).

42 The management of the 233 tunnels on the entire LNW route falls to a structures management engineer and an assistant structures management engineer within one of these teams. They are also responsible for the rest of the structures in the Lancashire and Cumbria area and all of the sea defences on the route.

43 The majority of the work carried out by the structures management staff is aimed at meeting the requirements of Network Rail company standard NR/L1/CIV/032, 'The management of structures'. This standard defines the procedures that have to be followed which aim to eliminate any unacceptable risk from Network Rail's structures to the operating railway. Supplementary requirements that apply specifically to tunnels are defined in Network Rail company standard NR/SP/CIV/084, 'Management of Existing Tunnels'. It contains a section on managing water in tunnels which includes the requirements for drainage and for handling problems with ice formation.

44 One of the other requirements in NR/SP/CIV/084 is that each tunnel must have a tunnel management strategy (see figure 7), which has three parts:

- The first part is a desk study which collates information about the tunnel. This includes information such as its general history, topography, nearby land use, ground conditions, construction, what features (such as shafts) are present, rail traffic levels and previous incident history. It can also include recommendations.
- The second part is a risk assessment which considers a series of defined risks which are scored as significant, minor or not applicable. Network Rail staff with knowledge of the structure participate in this assessment, so that local factors relevant to the structure are taken into account.

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[3] The types of structures that are managed are as defined in Network Rail company standard NR/L3/CIV/006/1C, 'Handbook for the examination of Structures Part 1C - Risk categories and examination intervals'. These are bridges, viaducts, tunnels, culverts, retaining walls and sea defences. This definition does not include earthworks such as embankments and cuttings.

- The third part is an action plan that identifies what needs to be done to mitigate the significant risks that have been identified.

45 The tunnel management strategy for Summit tunnel was produced in 2006 for Network Rail by Donaldson Associates, a consultancy firm. The structures management engineers use the information in the strategy to determine if the tunnel is susceptible to extreme weather events (paragraph 53). If it is, the tunnel is listed as a structure which is at risk in extreme weather (see paragraph 51 and figure 7).

### Network Rail Infrastructure Maintenance

46 Network Rail's infrastructure maintenance function manages the day-to-day maintenance and repair of the infrastructure. Each route is broken down into a number of areas that are led by an infrastructure maintenance engineer who is responsible for the maintenance of the railway track, signalling, telecommunications, electrification and plant assets. The infrastructure running through Summit tunnel, but not the tunnel itself, falls within the responsibility of the Preston infrastructure maintenance engineer.

47 Local maintenance engineers report to the Preston infrastructure maintenance engineer and they are responsible for the different assets within parts of the Preston infrastructure maintenance engineer's area. The Blackburn track maintenance engineer is responsible for the maintenance of the railway track through Summit tunnel, with staff based at Network Rail's maintenance depot at Blackburn carrying out the inspection and repair work.

48 Network Rail company standard NR/L3/TRK/1010, 'Management of responses to extreme weather conditions at structures, earthworks and other key locations', outlines the roles and responsibilities for the infrastructure maintenance function to protect the safety and operation of the line against the effects of extreme weather conditions. It applies to all infrastructure maintenance staff whose duties include track maintenance and inspection.

49 NR/L3/TRK/1010 calls for Network Rail's buildings & civils – asset management function to produce a local procedure, known as the extreme weather plan (see figure 7), covering the actions to be taken in the event of scour, storms, flooding or high tides. NR/L3/TRK/1010 defines the process for producing and reviewing the extreme weather plan, with the focus on sites that are at risk from flood, storm, scour and wave action. It does not mention the hazards or risks arising from extreme cold weather or ice.

50 The extreme weather plan is produced by Network Rail's buildings & civils – asset management function in accordance with NR/L1/CIV/032 (see figure 7). In section 9.3 of this standard it describes how the hazards arising from extreme weather (paragraph 53) must be managed and calls for the production of an extreme weather plan by the Territory Civil Engineer. This is a role that no longer exists, and there is no clear role within the current Network Rail organisation that replaces it. An outline for the plan is given in section 9.3.5 of NR/L1/CIV/032 and includes a statement that a procedure for the 'removal of ice from walls of a Tunnel' shall be considered for inclusion in the plan.

51 Network Rail's buildings & civils – asset management function produced an extreme weather plan for the northern section of the LNW route in May 2010, titled 'Extreme Weather Inspection of 'At Risk' Assets'. It was produced to meet the requirements of NR/L3/TRK/1010 and NR/L1/CIV/032. Network Rail's buildings & civils – asset management function also provided Network Rail's infrastructure maintenance function with the list of structures on their route that were at risk in different extreme weather conditions (see paragraph 53 for Network Rail's definition of extreme weather). This included Summit tunnel in a list of structures that were at risk in extreme cold weather.

## Network Rail Operations

52 Network Rail's operations function manages the operation of the railway system on a day-to-day basis. Its primary role is managing the safe movement of trains and this includes operating trains safely during extreme weather. The process that Network Rail operations follows for managing extreme weather events is documented in Network Rail's company standard NR/L2/OPS/021, 'Weather – Managing the operational risks'[4] (see figure 7).

53 NR/L2/OPS/021 defines what weather conditions Network Rail considers to be hazardous to the operation of trains, with levels of severity set for temperature, rain fall, snow fall, wind speed, etc. The air temperatures set for frost hazard levels are shown in table 1. Network Rail considers the weather to be adverse when one or more of these weather hazards are forecast to have a localised impact and present a medium level of risk to the operation of trains. Network Rail considers the weather to be extreme when one or more of these weather hazards are forecast in severe form or worse, or there are a combination of adverse weather conditions forecast, which will present a high level of risk to the operation of trains.

| Frost level | Minimum air temperature if wind <12 mph | Minimum air temperature if wind >12 mph | Severity |
|---|---|---|---|
| 1 | 0°C to -3°C | 0°C | Slight |
| 2 | -4°C to -6°C | -1°C to -2°C | Severe |
| 3 | -7°C or below | -3°C or below | Very severe |

*Table 1: The frost levels defined by Network Rail in NR/L2/OPS/021*

54 NR/L2/OPS/021 also states that each route must have a seasons delivery specialist. This person is responsible for planning, implementing and reviewing the arrangements on their route for seasonal or weather related issues.

55 The seasons delivery specialists from all of the routes have worked together to produce a guidance document called the 365 Weather Management manual (see figure 7). This describes the activities required to meet the requirements of NR/L2/OPS/021 and provides a single source of documentation that tells operations staff what they should do to manage and respond to weather related issues. It includes guidance on how to manage the operational risks that arise during extreme weather, such as heat, cold and high winds. There is national guidance for all of the routes, with additional area-specific guidance for each route in the appendices.

[4] Network Rail company standard NR/L2/OPS/021 became NR/L2/OCS/021 from 5 March 2011.

56 The area-specific guidance includes the key route strategy which is prepared by the relevant seasons delivery specialist. This strategy explains what steps should be taken by controllers when the weather conditions deteriorate to the extent that Network Rail's infrastructure maintenance and operations staff declare that their resources can no longer cope with maintaining the full network. At this point, operations control will implement a strategy that aims not to move the points at junctions, so main routes are kept running while sidings and other smaller sections of line are suspended from operational use.

57 One of the other functions of the seasons delivery specialist is to define the process for emergency weather action team (EWAT) conferences. EWAT conferences are convened when extreme weather conditions are forecast. They are led by a senior manager from within Network Rail's operations function and the attendees will include other key operations control staff, and senior staff from Network Rail's infrastructure maintenance function and the train operating companies. Its aim is to manage the possible disruption and the risks that the forecasted weather might cause to train services. After reviewing the risks, the EWAT conference will decide the plans and mitigations that they consider need to be put in place to maintain the safe operation of the railway.

58 The seasons delivery specialist can decide that an EWAT conference needs to be convened; part of their role requires them to monitor all of the weather forecast alerts for the route. Once an EWAT conference has been called for, the seasons delivery specialist will set the agenda and then participate in it. The seasons delivery specialist will record the decisions made during the EWAT conference. These decisions are then regularly reviewed and adjusted as new information is received, such as updated weather forecasts and reports from local staff, drivers, etc.

## Identification of the immediate cause[5]

59 **The immediate cause of the accident was that train 1P02 approached and struck a pile of ice on the track in Summit tunnel.**

60 When the driver first spoke to the signaller after the accident, he reported that his train had derailed after hitting a large pile of ice on the track. Afterwards, a significant amount of ice was found underneath ventilation shaft 10 (figure 8). The RAIB estimated that there was between 20 and 25 tonnes of ice on the track (figure 9).

61 A smaller, although still significant, volume of ice was also found underneath ventilation shaft 11 (figure 10). After the accident, further ice could be seen in the bottom of both of these shafts (figure 11).

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


*Figure 8: General view of the pile of ice found below ventilation shaft 10 after the accident (courtesy of British Transport Police)*


*Figure 9: Close up view of the pile of ice after the accident, with height and length shown*

*Figure 10: The pile of ice found under ventilation shaft 11 next to train 1P02*


*Figure 11: Views looking up at ventilation shafts 10 and 11 showing ice still present in the bottom of the shafts (ventilation shaft 11 photograph courtesy of British Transport Police)*

62 Marks made by the train on the track and tunnel wall showed that the train only ran derailed beyond the pile of ice. These marks, together with the lack of any marks showing that the wheels ran over the top of the running rails, indicated that the wheels on the front bogie had been lifted up as the train passed through the ice pile. The front wheels then came back down to the left of the running rails and into derailment 8.3 metres beyond the centre of the ventilation shaft 10. None of the following wheels were derailed as the front of the train had cleared sufficient ice from the track to allow them to pass through.

## Identification of causal[6] and contributory factors[7]

Ice formation

63 **Water running down the lining in ventilation shaft 10 froze and formed a large quantity of ice, which then began to thaw and fall onto the railway tracks below. This was a casual factor.**

64 The ice in ventilation shaft 10 was formed by water that froze as it ran down the lining of the shaft. This happened during a prolonged period of freezing weather conditions, when the ambient temperature fell below 0°C on 16 December and remained below freezing for the next 10 days. No trains ran through the tunnel for about 75 hours before the accident (paragraphs 24 and 25), so icicles that formed below the base of the ventilation shaft were undisturbed by trains. Also in other places where water was present, ice formed undisturbed on the tunnel walls and on the track (figure 12).


*Figure 12: Ice formations found on the track and tunnel wall*

65 A thaw began on 27 December when the ambient air temperature in the vicinity of the tunnel rose above 0°C at about 01:00 hrs. From about 04:30 hrs to the time of the accident, this outside air temperature stayed above freezing. The warmer outside air entered the tunnel over time but it is not known precisely how quickly the air temperature inside the ventilation shafts rose. As the air inside the ventilation shaft warmed up, the ice began to melt. Once it began melting, over a period of time it broke away and fell onto the tracks below. The pile was formed by many pieces of ice, of a range of sizes (figure 9).

66 It is not possible to be certain whether the ice found under ventilation shaft 10 was the result of one very large ice fall or whether it accumulated as a result of a number of smaller falls. The RAIB observed that ice was still present in ventilation shaft 10 after the accident (figure 11), so further falls were possible. Ice was also found under ventilation shaft 11, and more ice fell out of it and onto the top of the train while the passengers and train crew were waiting to be evacuated (paragraph 35). As the ice here was coming down as a series of falls, it is likely that the ice from ventilation shaft 10 fell in a similar way.

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

[7] Any condition, event or behaviour that affected or sustained the occurrence, or exacerbated the outcome. Eliminating one or more of these factors would not have prevented the occurrence but their presence made it more likely, or changed the outcome.

## Water seepage

**67 A causal factor was the volume of water seeping through the linings of ventilation shaft 10.**

68 The water that froze and formed the ice in ventilation shaft 10 had seeped through its lining. The tunnel bore and ventilation shaft linings in Summit tunnel are of brick construction and are not designed to be waterproof. Consequently there are many areas within the tunnel that are wet, and ventilation shafts 10 and 11 were known by Network Rail to be very wet areas.

69 The last detailed examination of ventilation shaft 10 took place in July 2006, and the examiner noted in the report that this shaft was very wet. The examiner first recorded it as being wet at 11 metres from its top and then getting progressively wetter down the remaining 76 metres of its length. No waterproofing or drip sheeting is fitted within ventilation shaft 10.

70 Witnesses told the RAIB that after the accident, water was pouring from ventilation shaft 11 onto the top of the train. While on site the RAIB also observed a lot of water flowing down the inside of ventilation shaft 10. During a follow-up site visit just over two weeks later, the RAIB observed water pouring from both of these ventilation shafts (figure 13). This water was overflowing the *ring dam*, running down the shaft's lining into the tunnel, and onto the tracks from the base of the shaft. Water was also cascading onto the tracks from a broken *downpipe* (paragraphs 140 to 143).

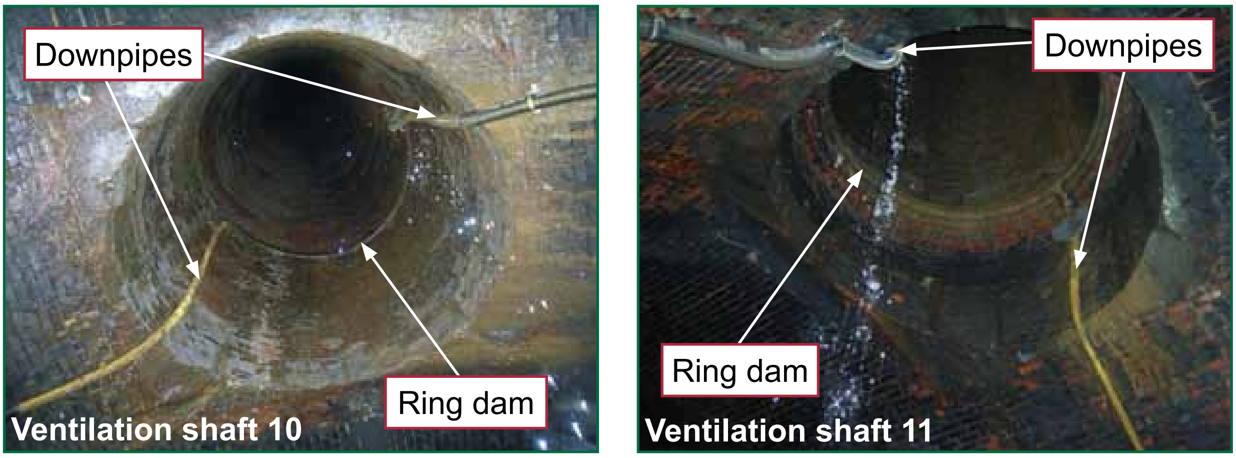


*Figure 13: Water cascading from ventilation shafts 10 and 11 onto the tracks below*

71 Summit tunnel passes through bands of rock which are all classified as water-bearing permeable rock. The permeability varies along the length of the tunnel as the rock type changes between sandstone, siltstone and mudstone. The rock types around ventilation shaft 10 allow groundwater to pass through them and when this groundwater meets the ventilation shaft lining, it passes through it and into the shaft.

72 The volume of water running down the ventilation shaft lining will therefore depend on the amount of water in the ground and the depth of the shaft. Ventilation shaft 10 (figure 14) would have been very wet at the time of the accident because:

- it is now Summit tunnel's deepest open shaft[8], measuring 87 metres from ground level to the base of the shaft at the crown of the tunnel; and
- water from melted snow would have been passing through the ground, as heavy falls of snow at the end of November melted when temperatures rose above freezing for seven days around the middle of December (figure 5).

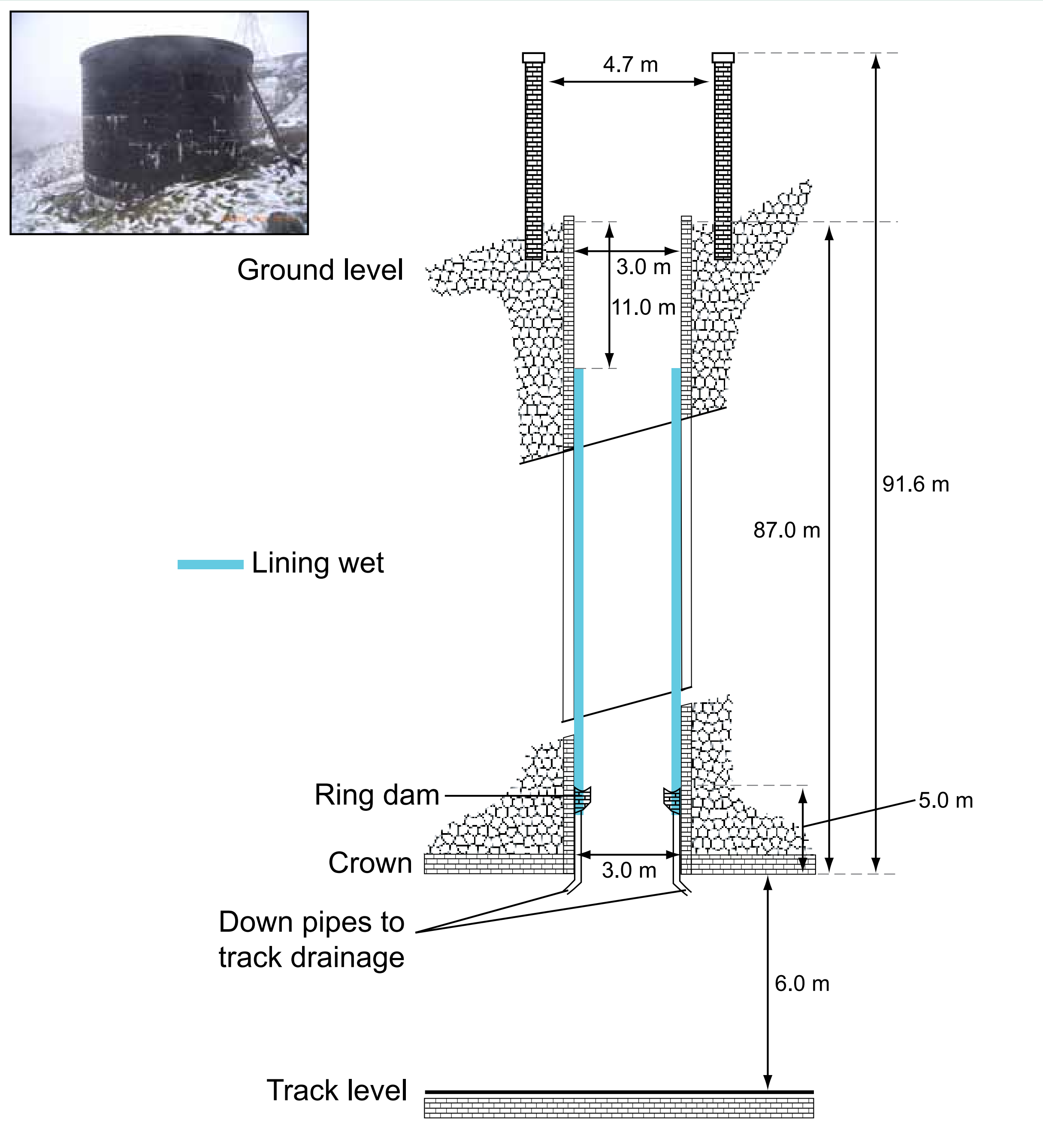


*Figure 14: Diagram showing dimensions and key features for ventilation shaft 10*

[8] Previously, ventilation shaft 9 was Summit tunnel's deepest open shaft but it was closed following a major fire in 1984.

73 The RAIB discounted rain or snow falling through the top of the open shaft as being the source of the water. The RAIB calculated the volume of water needed for the estimated quantity of ice that was found on the track, which showed that it was not feasible for this amount of water to have entered the open shaft as either rain or snow.

## Routine inspections

**74 The routine inspection regime did not identify the excessive amounts of ice that formed in the tunnel's ventilation shafts. This was a causal factor.**

75 The railway track through Summit tunnel is inspected by infrastructure maintenance staff on foot every two weeks in accordance with Network Rail company standard NR/L2/TRK/001/A01, 'Inspection and maintenance of permanent way – Inspection'. Trained infrastructure maintenance staff walk through the tunnel to carry out a basic visual inspection of the track and its components, with the objective of identifying any defects which, if uncorrected, could affect the safety or reliable operation of the railway before the next inspection. NR/L2/TRK/001/A01 requires these staff to observe the conditions of the track and also, 'to the extent that it is reasonable to do so', look at the other features along the railway. In section 8.8 part i) it lists these features and includes a bullet point list of items to observe for bridges and other structures, one of which is 'in cold weather – icicles causing risk to traffic'.

76 Infrastructure maintenance staff carried out the last basic visual track inspection before the accident on 19 December 2010. This was three days into the period of cold weather and the report of this inspection does not record that ice was seen within Summit tunnel. However, they had looked up ventilation shafts 10 and 11. On the lower parts of each shaft, they saw that a layer of ice had formed on the shaft lining. The amount of ice seen was not judged to be enough to present a risk to trains, so it was not reported.

77 The RAIB did not find any guidance for infrastructure maintenance staff on what to do when looking for ice formations, or how to judge the amount of ice that has built up, either within NR/L2/TRK/001/A01, or in any of the track work instructions. Ice that has formed on the track or the running rails is easily visible so staff can accurately assess the risk it presents. However, because of the depth of each ventilation shaft, it is very difficult for maintenance staff to see all of the ice up inside it, so they cannot accurately judge how much ice there is and assess the risk that it presents.

78 On 21 December 2010, the Blackburn assistant track maintenance engineer rode through Summit tunnel in the driving cab of a train in both directions. He was carrying out an additional cab riding inspection of the track, as basic visual track inspections had been suspended on other parts of the railway line because the track was covered in snow. In both directions he saw icicles in Summit tunnel that were large but not causing an obstruction. The sight lines from the cab meant he could see the ice hanging below the ventilation shafts but the amount of ice up inside the shaft could not be assessed. Similar comments were recorded for Dean Royd, Winterbutlee, Castle Hill and Horsfall tunnels which are in the same area (figure 3). None of the ice formations he saw caused him to recommend that a further closer inspection was needed in any of these tunnels.

79 No other inspections were planned that would have led to infrastructure maintenance staff passing through Summit tunnel. The next cab riding inspection was due to take place later on 28 December 2010. Inspections were taking place at the prescribed times, but in this case they were not frequent enough as excessive amounts of ice were able to form and go undetected in the time between the planned inspections.

80 Although no trains ran over this line for about 75 hours, after this length of time there is no requirement in Network Rail's company standards or in the Rule Book for an infrastructure maintenance inspection to take place before trains start running again, regardless of weather conditions. NR/L2/TRK/001/A01 only requires the railway to be inspected if the line is closed for more than one week.

### Additional inspections

81 **A causal factor was that the infrastructure maintenance staff did not carry out any additional inspections to look for ice or icicles in Summit tunnel.**

#### *Tunnel management strategy recommendation*

82 Part 1 of Summit tunnel's management strategy (paragraphs 44 and 45) recommended this tunnel should have an inspection regime for ice. It stated that 'A system needs to be established to allow the inspection of and removal of icicles in Summit Tunnel in cold weather'. These inspections for icicles would be in addition to the routine fortnightly basic visual track inspections by infrastructure maintenance staff (paragraph 75).

83 Part 1 of a tunnel management strategy does not normally include recommendations, but if the consultants producing this part of the strategy find information that requires actions to be taken, then they can record this requirement by making a recommendation. However, the recipients of the strategy, Network Rail's structures management engineers, do not have a process for handling any such recommendations.

84 Network Rail's structures management engineers did not implement this recommendation at the time. The RAIB found no evidence as to why this was (there is no known record of this decision). It is Network Rail's view that it was not implemented because there had only been two previous incidents recorded in Summit tunnel that involved ice; these had happened in 1982 and 1987 (see paragraph 136). Also, the structures management engineers thought that infrastructure maintenance staff would know that they should be carrying out such additional inspections and consequent ice removal.

#### *Extreme weather plan*

85 During 2010, Network Rail's buildings and civils – asset management function produced an extreme weather plan for the northern section of the LNW route and also a list of structures on the route at risk from extreme weather events (paragraph 51).

86 The plan aimed to provide infrastructure maintenance staff who go out onto the railway each day with guidance relating to buildings and civils engineering assets such as earthworks, drainage and structures. This included advice on what to look for during extreme weather and explained the purpose of the list of structures at risk. Ice in tunnels was identified as a specific risk and the guidance gave general advice on what infrastructure maintenance staff should do. Network Rail's buildings and civils – asset management function also wanted this information to be used as a guide on where to go first in extreme weather when structures might need to be looked at.

87 Network Rail's buildings and civils – asset management function prepared a presentation that recommended the extreme weather plan and list of structures were passed to track section managers and staff who carry out basic visual track inspections. However, the presentation itself did not state that there was a requirement for it to be briefed out. The presentation was first given to the Preston infrastructure maintenance engineer during a maintenance engineers meeting in August 2010 and no instruction was given at this meeting for it to be briefed out. Later that month the presentation was included as part of the formal technical briefing process that is used within Network Rail's infrastructure maintenance function. Consequently the Blackburn track maintenance engineer attended a briefing on 18 August 2010 that included the presentation. In September 2010, Network Rail also issued the briefing in booklet form, so that it could be used by staff who carry out basic visual track inspections. However, there is no record that either the briefing or the booklet were received by the local track section manager or staff who carry out basic visual track inspections in the Summit tunnel area.

88 The status of the extreme weather plan is not clear. It is titled 'Notes for guidance for competent persons inspecting 'At Risk' sites in extreme weather'. It also explains that it 'provides reference notes and guidance only for Buildings and Civils Asset Inspections by Maintenance at times of adverse and extreme weather'. The plan does not mandate that Network Rail's infrastructure maintenance function do anything; it only provides guidance about carrying out activities such as inspections. The plan does refer to NR/L3/TRK/1010 as the over-arching standard. In section 8 of NR/L3/TRK/1010, titled 'Responses', it states that Network Rail's infrastructure maintenance function shall:

- arrange for the inspection of the required sites;
- appoint a competent person to carry out and record details of this inspection;
- inspect the site in accordance with the extreme weather plan; and
- if the line is safe to remain open then the competent person shall continue to monitor the structure or if it is not safe to remain open then the competent person shall take steps to stop trains from running.

89 In summary, Network Rail's infrastructure maintenance function is required to follow the extreme weather plan but the plan itself does not convey this authority.

90 The Preston infrastructure maintenance engineer believed that much of the information contained in the presentation and extreme weather plan was already well known at Blackburn depot. He knew that information on what to do in extreme cold weather could also be found by his staff in track work instructions 3G023 'How to manage cold weather', and 3G024 'How to manage exceptionally low temperatures'. While these track work instructions do provide general guidance on what to do in extreme cold conditions, and the risk of ice forming in tunnels is mentioned, they are focused on what staff need to do to prepare themselves and their equipment for working in very low temperatures. The specific risks to structures due to ice formation are not covered.

*Local experience*

91 Apart from fortnightly basic visual track inspections, the infrastructure maintenance staff based at the Blackburn depot did not carry out any inspections to look for ice in Summit tunnel during periods of extreme cold weather. Staff within the buildings and civils – asset management function incorrectly assumed that the infrastructure maintenance staff would know that they had to go and do additional inspections for ice.

92 During periods of freezing temperatures and snowy weather in December 2010, the Blackburn track maintenance engineer was focused on keeping the railway open so that trains could continue running. To achieve this, he allocated his resources to snow clearing duties at the key junctions in his area, as required by the LNW key route strategy. This left insufficient resources to inspect all of the seventeen tunnels in his area even if he had chosen to do so.

93 The Blackburn track maintenance engineer had no recent knowledge of any incidents within Summit tunnel that involved ice or icicles. At the time of the accident, he been working for Network Rail for about eight years and had been in his current post for about two years. During this time he had seen ice and icicles in the tunnels in his area but they had not caused any major problems. He had found that although trains were striking icicles at times, it was not necessary for staff to be sent into the tunnel to remove them. The Blackburn track maintenance engineer was not aware of the incidents involving ice in Summit tunnel in 1982 and 1987 (paragraph 136).

94 For comparison the RAIB looked at how ice in Blea Moor tunnel is managed. This tunnel is 2404 metres long, is of brick arch construction dating back to 1876 and has three open ventilation shafts. It is located in Cumbria on the railway line between Settle and Carlisle. It falls within the area maintained by the Appleby track maintenance engineer who has been in this post since 2004 and has worked in the area since 1983. The track through the tunnel is maintained by staff based at Garsdale, and when a period of extreme cold weather sets in, they routinely go to Blea Moor tunnel to inspect it for ice and icicles. There is no instruction to do this; it is something that the staff know from their experience that they need to do, as this tunnel is known to suffer from ice formation in and around the ventilation shafts.

95 During the period of extreme cold weather at the start of December 2010, the Appleby track maintenance engineer noted ice forming in Blea Moor tunnel. He invited structures management staff to see the ice that had formed in one of the ventilation shafts (figure 15). The structures management staff looked at the ice formation and assisted the Appleby track maintenance engineer in deciding what the best way was to remove it without damaging the structure. The Appleby track maintenance engineer continued his contact with the structures management staff to actively look at ways to reduce ice formation in this tunnel and the methods of removing ice once it is found.

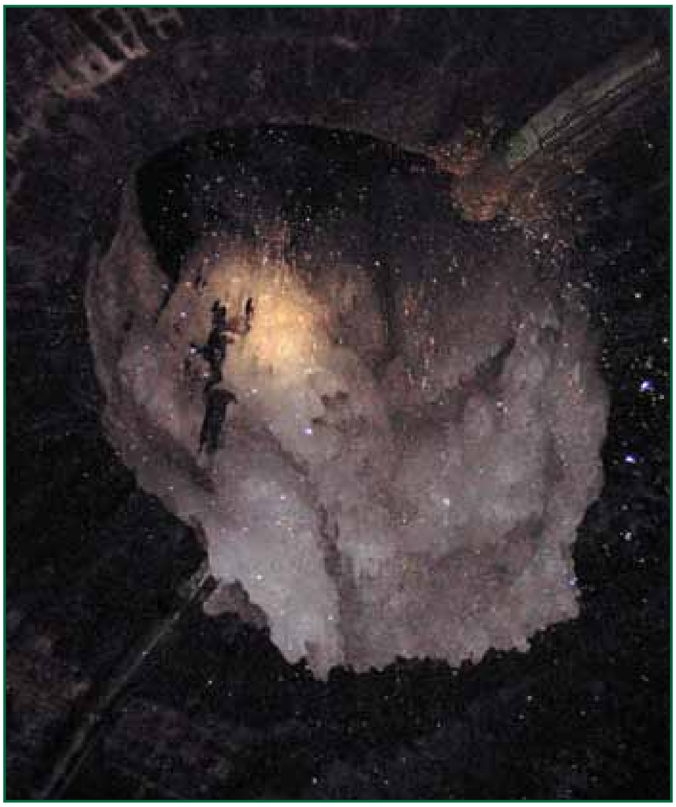

*Figure 15: The ice formation seen hanging from the bottom of a ventilation shaft in Blea Moor tunnel in December 2010 (courtesy of Network Rail)*

Train 1P02 approached the fallen ice at the permitted line speed

96 **A causal factor was that train 1P02 was allowed to pass through Summit tunnel at the normal permitted speed for the line.**

*Tunnel management strategy action plan*

97 Part three of the tunnel management strategy for Summit tunnel, the action plan (paragraph 44), did include a risk mitigation for ice formation that called for a speed or operating restriction to be put in place after a cold night.

98 The tunnel management strategy risk assessment (paragraph 44) had identified a risk to the tunnel from freeze-thaw erosion because groundwater was present, and made a specific note that there was a history of large icicles forming in the tunnel. Because of the hazard of icicles obstructing trains, this risk was rated as significant. However, the risk assessment did not consider the hazards or risks associated with thaw conditions or extended periods of route closure during extreme weather.

99 To mitigate the risk of icicles, the action plan called for the first trains through the tunnel to run at a reduced speed after a heavy frost so that they could look for icicles. However, the RAIB found no evidence that this mitigation measure was ever put in place by Network Rail operations. There is no evidence of it being included in the *sectional appendix* for the route or in a *local instruction* at the signal box.

*No action taken by the signaller*

100 The RAIB found no operating restrictions or signal box local instructions in place at Preston power signal box that required the signaller to take any specific action before allowing a train to pass through the tunnel in any particular weather conditions.

101 Had the signaller been required to do so, he could have stopped train 1P02 and instructed its driver to examine the line. Examining the line is a process where a signaller will instruct a driver to pass over a line at a speed not exceeding 10 mph (16 km/h) (for lines in a tunnel), so that he can visually check that it is safe for trains to pass over and be ready to stop if required. The signaller did not do this because he had no concerns over the status of the line, as there had been no reports of ice or icicles from:

- train drivers, as no other trains were running; or
- infrastructure maintenance staff, as no routine inspections or engineering work had taken place in the tunnel.

*No action taken by LNW route control*

102 The signaller had not received any specific instructions from LNW route control asking him to instruct the first train through the tunnel to examine the line. No one at LNW route control level had anticipated a problem with resuming the train service after just over three days with no trains running.

103 Network Rail can sometimes arrange for additional trains to run over a section of line to check its status before the planned train service then runs over it. These trains are known as route proving trains.

104 On the LNW route on 24 December 2010, arrangements were made for three diesel locomotives fitted with miniature snow ploughs to be in place at locations on the west coast main line from 27 December, so that they could be used for snow clearance duties and route proving if required. Two electric locomotives were also planned to run over the west coast main line to keep the overhead electric wires clear of ice. LNW route control also arranged for a diesel locomotive to be available, if required, for proving the route between Birmingham and London Marylebone. However, LNW route control did not plan to run route proving trains over any other lines.

Emergency Weather Action Team (EWAT) conferences

105 **The Emergency Weather Action Team conference did not identify the risk presented to trains by ice and icicles when resuming the train service. This is a possible causal factor.**

106 When the spell of extreme cold weather began, EWAT conferences were held on each day from 20 to 24 December. The records for these conferences show that no issues specific to Summit tunnel, nor the resumption of train services after the Christmas break, were discussed.

107 On 25 and 26 December, no EWAT conferences were held as there was no train service operating on those days, and reduced staffing levels over the Christmas period meant that some of the attendees were not available. On 27 December when train services began operating again, no EWAT conferences took place because the weather conditions had now begun to improve, with temperatures rising above freezing, and the weather conditions were forecast to continue improving. As there was no weather forecast alert to cause a conference to be called, no discussions took place to consider what weather related risks might still be present before resuming the train service.

108 The minutes of the EWAT conferences that were held before the Christmas period show that the risk posed by ice and icicles to the operation of trains was not raised by any of the attendees. Guideline agendas are included in the 365 weather management manual (paragraph 55) as checklists for the EWAT conference to follow. There is a guideline agenda for EWAT conferences which are held when snow, frost or ice weather forecast alerts are received, but it does not cover any of the risks posed by ice formation or the subsequent thaw. The risk of flooding due to snow melt is included on the guideline agenda but risks such as ice falling onto track during a thaw are not.

109 The guideline agenda also includes an item that calls for the EWAT conference to look at whether the prevailing weather conditions will increase the risk of ground-heave or an earthworks failure. It does not include a similar item asking for the EWAT conference to consider if the weather will increase the risk of a problem with any of the structures on the route.

110 The structures management engineers had identified and listed which structures on LNW route were at risk in different extreme weather conditions. They had sent this list to the LNW seasons delivery specialist but due to an oversight this information was not included in the 365 weather management manual. Consequently, the EWAT conference attendees did not consider the risks of operating trains over or through those structures that were at risk in the extreme cold.

111 If this item had appeared in the guideline agenda, or otherwise been discussed at the EWAT conference, the need to inspect tunnels for ice, or the need to examine the line using trains, might have been identified. If subsequent actions had then been taken, the accident might have been averted.

## Incidents in Morley tunnel

112 Had two incidents in Morley tunnel on the day before the Summit tunnel accident been communicated within Network Rail, this accident might have been avoided. However, there is no conclusive evidence that such communication would have resulted in actions being taken at Summit tunnel.

113 Morley tunnel is located on the railway line between Leeds and Huddersfield on the London North Eastern (LNE) route; it is 20 miles (32 km) from Summit tunnel. At about 06:30 hrs on 27 December 2010, the first east-bound train to run through the tunnel since before Christmas struck icicles hanging from the bottom of a ventilation shaft, and the driver’s windscreen was broken. Later that day at about 14:30 hrs, another east-bound train struck a large quantity of ice lying on the track below a ventilation shaft. The train remained on the rails but some of the equipment underneath the train was damaged.

114 In both cases, the train drivers contacted the signaller at Batley signal box to report what had happened. The signaller then reported the incidents to LNE route control and fault reports were raised which required Network Rail infrastructure maintenance to attend. Infrastructure maintenance staff arrived at the tunnel at 08:35 hrs but they were unable to carry out a full inspection of the tunnel because their request for a longer period of access was refused by the signaller. They returned later that evening and found and removed ice from ventilation shafts within the tunnel.

115 According to Network Rail's process, LNE route control staff should have categorised and recorded these types of incident as 'weather related problems'. This category of incident must be reported to Network Rail's national operations control centre if the line is blocked or if it leads to more than 200 minutes of train delays. However, the RAIB could not find records for either of these incidents on Network Rail's control centre incident logging system which the national operations control centre regularly monitor. LNE route control staff were aware of both incidents as they had raised the fault reports, but the RAIB could not establish why they were not included in the control logs. Consequently, neither incident was seen by Network Rail's national operations control centre, which is responsible for disseminating information within Network Rail. The national operations control centre keeps Network Rail's management team informed of operating incidents and day-to-day service disruptions which have an effect on the railway network. This allows senior managers throughout Network Rail's organisation to be aware of real time problems and gives them an opportunity to respond.

116 As the events that happened in Morley tunnel were not recorded by LNE route control, the opportunity was lost for someone to identify these incidents and recognise that there was a risk of ice formation in tunnels and ventilation shafts after a period with no trains running, and to trigger action at a local or national level. For example, after the accident in Summit tunnel, Network Rail's head of asset management (structures) issued an instruction which was disseminated nationally by the national operations control centre. It called for Network Rail to identify those tunnels which had a significant build up of ice and to consider putting operating restrictions in place if there was a risk of derailing a train. If the incidents in Morley tunnel had initiated similar local or national actions, then an inspection of Summit tunnel, which also runs under the Pennines and is only 20 miles away, might have taken place and the accident might have been averted.

## Identification of underlying factors[9]

117 The RAIB identified four underlying factors. These were:

- the LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of passing safety related information to other parts of Network Rail's organisation and then getting confirmation that it has been acted upon;
- the LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of getting other parts of Network Rail's organisation to implement necessary safety actions that fall outside of their direct control;
- in this instance, Network Rail had not considered what the effects of extreme cold weather would be during periods when no trains were running; and
- Network Rail had not considered, as part of its weather management processes, what risks there might be to the operation of trains when thaw conditions set in after a period of extreme cold weather.

### Network Rail's organisation

#### *Safety related information*

118 **The LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of passing safety related information to other parts of Network Rail's organisation and then getting confirmation that it has been acted upon.**

119 The RAIB found no evidence that the LNW route structures management engineers were not complying with Network Rail's company standards for managing Summit tunnel. This included producing information, such as the tunnel management strategy action plan and including the tunnel on the list of structures at risk in extreme weather conditions, both of which could be categorised as being safety related information.

120 Functions within Network Rail's organisation, such as buildings and civils, infrastructure maintenance and operations, only have formal lines of communication with each other at a very senior level. There is communication at a working level between staff in different parts of the organisation, but only on an informal basis.

121 The RAIB did not find a defined process for the safety related information prepared by the LNW route structures management engineers to be passed to other parts of Network Rail's organisation such as infrastructure maintenance or operations. Consequently no feedback is received so there is no means of knowing if this information has been delivered to, received by, or acted upon by the correct person.

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

122 Using the list of structures at risk in extreme cold weather as an example:

- within operations, this information was not included in the 365 weather management manual by the LNW seasons delivery specialist for control staff to refer to (paragraph 110); and
- within the Preston infrastructure maintenance engineer's area, this information was not briefed out to section managers and staff who carry out track inspections, as had been recommended when building and civils passed the information over (paragraph 87).

*Safety related actions*

**123 The LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of getting other parts of Network Rail's organisation to implement necessary safety actions that fall outside of their direct control.**

124 The RAIB found that work undertaken by, or produced on behalf of, the LNW route structures management engineers had identified the risk presented by ice in Summit tunnel and called for action to be taken to mitigate the risk. However none of these actions were carried out:

- an action in part 3 of the tunnel management strategy called for Network Rail operations to make the first trains through Summit tunnel run at a reduced speed after a heavy frost, so that they could inspect for icicles (paragraph 98), but this action was not carried out; and
- Summit tunnel was included on the list of structures at risk in extreme cold weather, so Network Rail infrastructure maintenance should have inspected it for ice (paragraph 88) but this did not happen.

125 The structures management engineers control the management of the tunnels, including the examination regime and maintenance work on the tunnel itself. For the items falling within their control, they have limited access to resources within Network Rail to carry out work, but there are contractors they can call on for examinations and minor repair works. As such the structures management engineers do have the ability to take action for items that fall within their direct control.

126 For actions that fall outside of their direct control, such as the items listed in paragraph 124, the LNW route structures management engineers rely on the co-operation of others. They do participate in meetings with infrastructure maintenance and operations and can suggest or try to influence what is done. However, they have no formally documented authority to get infrastructure maintenance or operations staff to carry out any of the actions their work has identified as being necessary.

## Weather management

### *No trains running*

**127 In this instance, Network Rail had not considered what the effects of extreme cold weather would be during periods when no trains were running.**

128 When there are no trains running over a section of railway during periods of extreme cold weather, icicles can grow undisturbed on structures, ice can form on the track and on the top of the rails, and ice falls can happen. However, none of these potential hazards will be noticed if there are no train drivers regularly observing the state of the railway line.

129 When no trains are running, the risk of ice formation and subsequent ice falls can increase as it is possible for icicles to grow much more quickly. Research[10] has shown that the tip of an icicle is one of the key factors in how large and quickly an icicle will grow. If the tip is removed, the icicle's rate of growth is slowed. Therefore when trains are running regularly and just clipping the tips of icicles, they slow the icicle's rate of growth sufficiently to maintain a clear path for subsequent trains to pass through. However, if there is a period when no trains are running, then the icicles can grow undisturbed and can be large enough to be in the path of the next train and can cause damage to it, eg the windscreen of the first train through Morley tunnel after Christmas was damaged (paragraph 113). Large icicles are also very heavy and they can become detached at their root when their weight overcomes the ice's adhesion strength to the structure. This can then lead to an accumulation of ice on the track. Ice falls onto the track are also much more likely once a thaw starts as the research also states that the adhesion strength of ice and its structural strength are both low at close to 0°C.

130 Large icicles and ice falls could be encountered by any train. However, the first train to pass over the railway line after a period of very cold weather is the one which is most likely to encounter an ice obstruction.

131 Periods when no trains are running are not uncommon and are not restricted to the Christmas holiday period. Railway lines can be closed when engineering works are taking place and *possession* times can run to a number days. In such cases, before the line is handed back to Network Rail operations, the section of railway within the limits of the *worksite* is inspected to make sure it is safe for trains to start running again. However, while the engineering work is in progress, there may be parts of the railway that are not within the worksite itself, but over which no trains run. These may not be inspected before the train service resumes. It is also possible for parts of the railway to be closed for an extended period if the key route strategy is implemented during extreme cold weather.

[10] A Model of Icicle Growth, L Makkonen, Journal of Glaciology, volume 34, Number 116, 1988.

132 Network Rail operations manages extreme weather events in accordance with NR/L2/OPS/021 (paragraph 52) and section 4.7 describes the criteria for resuming the train service after a suspension or curtailment of services. It calls for a structured process to be adopted based on information from updated weather forecasts, physical inspection, weather information tools and conferences between relevant parties. Although there was no abnormal suspension or curtailment of services, all of Northern Rail's services were cancelled due to industrial action on the day before, so train 1P02 was the first train to pass through Summit tunnel for 75 hours. Network Rail operations control was aware of the extreme cold weather conditions that there had been over the previous few days, so this process could have been applied had the risk been recognised.

133 The RAIB found no evidence of a physical inspection or a conference taking place before train 1P02 ran, nor that Network Rail operations control considered what measures might be needed before allowing trains to run over this line at the permitted line speed. This issue was not discussed at the EWAT conferences before Christmas; it is not an item on the guideline agenda (paragraph 108). The LNW route controllers did not instruct the staff in Preston signal box to make train 1P02 run at a reduced speed (paragraph 102), and nor did they arrange for a route proving train to run over that line before train 1P02 (paragraphs 103 to 104). Network Rail infrastructure maintenance were only required to carry out an inspection if the railway is closed for more than seven days (paragraph 80).

*Consideration of thaw conditions*

134 **Network Rail had not considered, as part of its weather management processes, what risks there might be to the operation of trains when thaw conditions set in after a period of extreme cold weather.**

135 Network Rail's weather management processes, such as the EWAT conferences, are focused on preparing for cold weather events. The EWAT conference agenda for snow, frost and ice does include an item referring to the risk of flooding due to snow melt, but there is no mention of any risk from thawing ice, including ice falling onto the track. The RAIB found no mention in Network Rail's company standards or documents for weather management about the effects of thaw conditions on ice formations, especially the risk of ice falling onto the track.

## Previous occurrences of a similar character

136 Network Rail's management strategy for Summit tunnel includes a history of incidents and includes two entries related to ice:

- In January 1982, problems were reported with a large amount of ice on and between the tracks in places, particularly beneath closed ventilation shaft 9 and open ventilation shafts 10 and 11. Most of the ice had melted by the following day except for that beneath ventilation shafts 10 and 11. Here the icicles hanging below the shaft were 3.6 metres (12 feet) long and up to 0.9 metres (3 feet) wide.
- In January 1987, a train reported hitting an object near ventilation shaft 11. A subsequent inspection noted that the train had hit ice. Other icicles were removed from the tunnel roof throughout the tunnel, but the ice within the ventilation shafts could not be reached.

137 The RAIB searched a national rail industry system for similar incidents in Summit tunnel since 1990 but none were found. A wider search for incidents involving trains striking ice or icicles in other tunnels listed ten such incidents. These all involved train drivers reporting that their train had struck an object in a tunnel which resulted in little or no damage. Subsequent examinations by the next train through or infrastructure maintenance staff found ice or icicles at the reported location.

138 The RAIB searched Network Rail's control centre incident logs for entries relating to ice or icicles in tunnels from when the extreme cold weather started on 16 December 2010 to just before the accident. During this period, 43 incidents were recorded, including eight on the 27 December, but not including those that went unreported in Morley tunnel (paragraphs 112 to 115). Thirteen of these incidents involved trains striking ice or icicles and on two occasions the train's windscreen was broken. The majority of reports were made by train drivers, although Network Rail infrastructure maintenance staff reported eight of the incidents and electrification and plant staff reported a further five.

## Severity of consequences

### Train speed

139 The speed of train 1P02 through the tunnel affected the severity of the accident. Had the train been travelling at its permitted speed of 70 mph (113 km/h), it would have struck the pile of ice, and then the tunnel wall, with greater force. This might have caused injuries to the passengers or train crew. In contrast, had the train driver been instructed to pass through the tunnel at a much reduced speed, he might have been able to stop the train short of the ice, or struck the ice with a much reduced force.

## Observations[11]

### Ventilation shaft 10 and 11 drainage defects

140 The last detailed examination of the tunnel bore by an examiner from Amey included a visual examination of the ventilation shaft drainage from below. This took place over two weekends at the end of July and the start of August in 2010. The examiner found the downpipe to the ring dam was broken in ventilation shaft 11 (figure 16) and called for it to be reinstated to prevent water being discharged onto the track. For ventilation shaft 10, the examiner found the ring dam was not collecting the water running down the shaft and called for a review of the existing drainage arrangements with actions to be taken to correct this.

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

*Figure 16: The broken downpipe in ventilation shaft 11*

141 The broken downpipe was noted by a senior structures management engineer who was on site at time of the examination, and he entered this defect as a minor works item on CARRS the following week. However, it was not repaired before the accident because it was not classified as an urgent repair. Network Rail buildings and civils – asset management had reprioritised all non-urgent repairs to the next financial year starting in April 2011, because the minor works budget for LNW route for that financial year was already fully committed. The RAIB observed during a site visit in January 2011 that neither defect had been repaired.

142 The drainage defects in both ventilation shafts 10 and 11 continued to discharge water directly onto the tracks below. In freezing weather, this water can form ice on the track and on the top of the rails which could cause a derailment.

143 The RAIB did not find that the drainage defects in either ventilation shaft were causal to the accident. During the extended period of freezing weather, water seeping into the ventilation shafts would have frozen on the linings and in the ring dams and the ice that formed would have blocked up the drainage system. In such extreme weather conditions, this type of drainage arrangement is always susceptible to freezing up, even if it is in perfect working order.

Late submission of Amey tunnel examination report

144 After the last detailed examination for Summit tunnel was completed by Amey in August 2010 (paragraph 140), the examination report should have been submitted to Network Rail within four weeks of it taking place. The RAIB found the report had not been submitted at the time of the accident, almost five months later. Network Rail LNW monitor whether examinations take place but do not check whether the associated report has been submitted. Amey provided an incomplete version of the report later on the day of the accident. Network Rail required a completed version of the report which was provided by Amey in February 2011 and accepted by Network Rail in March 2011.

145 The delay in the submission of the last detailed examination report meant there was a significant delay in the defects recorded by the examiner being entered as work items on CARRS. This caused a corresponding delay in planning the repair of the defects that had been found, which was significant for those defects which the examination report recommended be repaired within a short timescale.

Re-opening routes closed after implementing the key route strategy

146 The 365 weather management manual contains the key route strategy (paragraph 56) for the route. The strategy lists items such as those points that must remain functional at all times, points that can be left in one position and those routes and sidings that can be abandoned during extreme cold weather.

147 Network Rail's key route strategy for LNW route does not define what factors need to be considered before reopening a route that has been abandoned (although this was not the situation for the route through Summit tunnel). There is no requirement for the line to be examined although NR/L2/OPS/021 describes the high level criteria for resuming the train service after a suspension or curtailment of services (paragraph 132). As the key route strategy does not state what needs to be done, it was likely that the train services would resume without any checks being made.

# Summary of Conclusions

## Immediate cause

148 The immediate cause of the accident was that train 1P02 approached and struck a pile of ice on the track in Summit tunnel (**paragraph 59**).

## Causal factors

149 The causal factors were:

a. the water running down the lining in ventilation shaft 10 froze and formed a large quantity of ice, which then began to thaw and fall onto the railway tracks below (**paragraph 63, Recommendation 1**);

b. the volume of water seeping through the linings of ventilation shaft 10 (**paragraph 67, Recommendation 1**);

c. the routine inspection regime did not identify the excessive amounts of ice that formed in the tunnel's ventilation shafts (**paragraph 74, Recommendation 4**);

d. the infrastructure maintenance staff did not carry out any additional inspections to look for ice or icicles in Summit tunnel (**paragraph 81, Recommendation 4**); and

e. train 1P02 was allowed to pass through Summit tunnel at the normal permitted speed for the line (**paragraph 96, Recommendation 2**).

150 It is possible that the following factor was causal:

a. the risk presented to trains by ice and icicles when resuming the train service was not identified by the Emergency Weather Action Team conference (**paragraph 105, Recommendation 3**).

## Underlying factors

151 The underlying factors were:

a. the LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of passing safety related information to other parts of Network Rail's organisation and then getting confirmation that it has been acted upon (**paragraph 118, Recommendation 5**);

b. the LNW route structures management engineers in Network Rail's buildings and civils – asset management function had no formal means of getting other parts of Network Rail's organisation to implement necessary safety actions that fall outside of their direct control (**paragraph 123, Recommendation 5**);

c. in this instance, Network Rail had not considered what the effects of extreme cold weather would be during periods when no trains were running (**paragraph 127, Recommendation 2**); and

d. Network Rail had not considered, as part of its weather management processes, what risks there might be to the operation of trains when thaw conditions set in after a period of extreme cold weather (**paragraph 134, Recommendation 3**).

## Additional observations

152 Although not linked to the accident on 28 December 2010, the RAIB observes that:

a. the drainage defects in ventilation shafts 10 and 11 were discharging water directly onto the tracks below which in freezing weather can form ice on the track and on top of the rails (**paragraph 142, Recommendation 1**);

b. the delay in the submission of the last detailed examination report led to a significant delay in the defects recorded by the examiner being entered as work items on CARRS (**paragraphs 145 and 156 to 158**); and

c. Network Rail's key route strategy for the LNW route does not define what factors need to be considered before reopening a route that has been abandoned (**paragraph 147, Recommendation 2**).

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

153 The seasons delivery specialist for LNW route has asked Network Rail's weather forecast provider to issue two new alerts when low temperatures are recorded. If the ambient air temperature has been continuously below 1°C for three consecutive days, a yellow alert is issued. This alert is to be used to get infrastructure maintenance staff to prepare to carry out additional inspections for ice and icicles. If the ambient air temperature has been continuously below 1°C for five consecutive days, a red alert is issued. When this alert is issued, infrastructure maintenance staff will be mobilised to carry out additional inspections for ice and icicles. A red alert will then be issued each day while the ambient air temperature remains continuously below 1°C.

154 Network Rail has also installed temperature sensors in Summit tunnel (because the accident happened in it) and Blea Moor tunnel (because of its altitude and history of ice formation). Network Rail plans to use the data collected from these sensors to better understand how the temperature inside the tunnel correlates with the outside ambient temperature at the nearest weather station, and then use this knowledge to refine the trigger levels for the low temperature alerts.

155 Network Rail is also planning to use consultants and launch a project to look at potential short and long term approaches for managing ice formation in tunnels. This is an initiative which is being led by both the buildings and civils, and operations functions. Network Rail wants to get a wider view by using a consultant and wants to identify what measures can be taken for higher risk tunnels, especially those with shafts. The aim of the research strategy is to better understand the circumstances that cause major ice build up, so better decisions can be made as to which structures are at risk and what the key factors are, eg shaft depth, wind direction, etc. A future step would then be the production of software to predict when ice will be a risk at a structure.

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

156 The Office of Rail Regulation carried out a project during 2010 and 2011 which investigated Network Rail's management of its structures. This work included determining if Network Rail was implementing its examination arrangements for structures, identifying critical defects and taking appropriate action. The Office of Rail Regulation found a number of deficiencies in how Network Rail was managing its structures. One such deficiency was that Network Rail did not have a robust way of identifying when an examination report for a structure had not been loaded into CARRS, ie the report's submission was overdue. On 20 May 2011, the Office of Rail Regulation issued Network Rail with an *improvement notice*[12]. To comply with this notice, the Office of Rail Regulation requires Network Rail to ensure that structures are fully examined and that examination reports are evaluated at appropriate intervals.

157 The RAIB is investigating an accident that happened on 5 February 2011, when a passenger train derailed after striking rubble as it approached Dryclough junction in Halifax. The rubble had fallen from a section of dry stone retaining wall that had collapsed. This investigation has also identified that Network Rail has no means of identifying when an examination report has not been loaded into CARRS and intends to make a recommendation that will address this issue.

158 Given that the above activities encompass the factor identified in paragraph 145 (relating to the late submission of examination reports), the RAIB has decided not to issue a further recommendation.

[12] Office of Rail Regulation Improvement Notice I/303293339/JPMcG

# Recommendations

159 The following recommendations are made:[13]

**Recommendations to address causal, contributory, and underlying factors and observations**

1 *The intent of this recommendation is to reduce the amount of ice forming in Summit tunnel's ventilation shafts by improving the arrangements for managing the water seeping through the shaft's lining, eg by changing the drainage arrangements. These changes should also stop the water from falling directly onto the tracks below.*

Network Rail should review how the arrangements for managing water within Summit tunnel can be improved, decide what actions it is reasonably practicable to take, and implement them. The review should specifically consider what can be done to manage the water seeping through the ventilation shaft linings and reduce the amount of ice forming during periods of freezing temperatures (paragraphs 149a, 149b and 152a).

2 *The intent of this recommendation is to prevent the first train, after a cessation of traffic due to extreme weather, from passing at the line's maximum permitted speed through or over an unsafe structure. By identifying which structures on a route are at risk of becoming unsafe due to extreme weather, Network Rail can then check their state prior to reopening the route, eg by using the first service train to examine the route, a route proving train or staff on foot.*

Network Rail should identify the structures (as defined in NR/L3/CIV/006/1C) where passengers or staff might be put at risk when train services are resumed following an extended cessation of traffic during, or following, periods of extreme weather (as defined in NR/L2/OPS/021). Network Rail should then put in place procedures that result in checks that it is safe for trains to operate at the permitted line speed over or through these structures before resuming the train service (paragraphs 149e, 151c and 152c).

*continued*

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[13] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation to enable it to carry out its duties under regulation 12(2) to:

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

(b) report back to 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 167 to 171) can be found on RAIB's website www.raib.gov.uk.

3 *The intent of this recommendation is to ensure that the hazards of ice formation on structures and the subsequent hazards during thaw conditions (eg ice falls onto the track) are included throughout Network Rail's weather management processes, so that they can be risk assessed and mitigated. For example, extreme cold weather events are not specifically included within NR/L3/TRK/1010 and EWAT conferences do not consider the hazards that might be present when operating trains once extreme cold weather conditions end and a thaw sets in.*

Network Rail should review and implement changes to its weather management processes to take into account the potential hazards created by extreme cold weather events and subsequent thaw conditions (paragraphs 150a and 151d).

4 *The intent of this recommendation is to give Network Rail staff the skills and knowledge to carry out additional inspections to look for ice on structures during periods of extreme cold weather, as Network Rail infrastructure maintenance's routine inspection regime may be too infrequent. Staff need to know what they need to do, where and when they should be doing it and the actions they should take once ice is found. This will support the implementation of NR/L3/TRK/1010 and the extreme weather plan, which require these additional inspections to take place. The staff undertaking these inspections should also know what potential hazards may be present and understand how to do the inspections while maintaining their own safety.*

Network Rail should provide training and information to its staff on carrying out the inspections of those structures which are at risk from ice in extreme cold weather. The training and information should include guidance on managing the hazards to staff while carrying out these inspections (paragraphs 149c and 149d).

5 *The intent of this recommendation is for safety actions and safety related information originating from Network Rail's buildings and civils – asset management function to be managed to an appropriate conclusion when it is passed to other parts of Network Rail's organisation.*

Network Rail should put in place processes for the management and distribution of safety actions and safety related information originating from Network Rail's buildings and civils – asset management function. This should include a process for systematically reviewing the resolution of necessary safety actions and a process for passing safety related information to other parts of Network Rail's organisation, including confirmation that it has been received, understood and acted upon (paragraphs 151a and 151b).

# Appendices

## Appendix A - Glossary of abbreviations and acronyms

| | |
|---|---|
| CARRS | Civil Asset Register and electronic Reporting System |
| CEFA | Civils Examination Framework Agreement |
| EWAT | Emergency Weather Action Team |
| L & Y | Lancashire & Yorkshire |
| LNE | London North Eastern |
| LNW | London North Western |

## 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.

| | |
|---|---|
| Autocoupler | A device which simultaneously couples two rail vehicles together mechanically, electrically and pneumatically.* |
| Basic visual track inspection (patrol) | A visual inspection of the track, carried out on foot, which aims to identify any immediate or short term actions that are required. Often referred to as a track patrol. |
| Bogie | An assembly of two *wheelsets* in a frame which is pivoted at the end of a long vehicle to enable the vehicle to go round curves. |
| Chain | A unit of length equal to 66 feet or 22 yards (20.1168 m). There are 80 chains in one standard mile.* |
| Continuous welded rail | On Network Rail, a rail of length greater than 36.576 m (120 feet), or 54.864 m (180 feet) in certain tunnels, produced by welding together standard rails or track constructed from such rails.* |
| Diesel multiple unit | A train consisting of two or more vehicles, semi-permanently coupled together, with a driving cab at each end. Some or all vehicles are equipped with axles powered by one or more diesel engines. |
| Down | The name in the report given to lines used by trains travelling in the direction of Leeds. |
| Downpipe | A pipe for carrying water from a gutter to the ground or to a drain. |
| Emergency brake | The (abnormal) full application of all available braking effort, sometimes using a more direct and separate part of the control system to signal the requirement for a brake application than that used for the full service application. On certain vehicles, the retardation rate may be specified to be higher than that of the full service braking application.* |
| Emergency call | A direct call, which is given a high priority, that can be made by a network controller to the driver of a specific train over a dedicated radio network operated and maintained by Network Rail. |
| Full service brake | A full (non-emergency) brake application.* |
| Improvement notice | An order from an enforcing authority such as the Office of Rail Regulation, requiring a company to take action where there has been a breach of the Health and Safety at Work Act. |
| Local instruction | Documents issued by the relevant route mandating the method of operation for a particular location or circumstance.* |

| | |
|---|---|
| On-train data recorder | Equipment fitted on-board the train which records the train's speed and the status of various controls and systems relating to its operation. This data is recorded to a crash-proof memory and is used to analyse driver performance and train behaviour during normal operations or following an incident or accident. |
| Panel | A section of the control desk of a power signal box.* |
| Permitted speed | The maximum speed at which trains may safely negotiate a section of track, as published in the sectional appendix. |
| Possession | Period of time that a section of the railway is blocked to service trains so that engineering work can be safely carried out. |
| Power signal box | A large signal box which controls the junctions and signals over a large area by electrical means.* |
| Ring dam (or Garland) | A circular channel fixed around the inside of a tunnel shaft just above the opening into the tunnel bore, intended to catch water running down the sides of the shaft.* |
| Road-rail excavator | An excavator that has been adapted to make it capable of running on railway track as well as on the road. |
| Sectional appendix | An operating publication produced by Network Rail that includes details of running lines, permitted speeds, and local instructions. |
| Sleeper | A beam made of wood, pre- or post-tensioned reinforced concrete or steel placed at regular intervals at right angles to and under the rails. Their purpose is to support the rails and to ensure that the correct distance is maintained between the rails.* |
| Track circuit | An electrical circuit in the running rails that detects the presence of a train. |
| Track circuit operating clip | A pair of spring clips connected by a wire, used to short out track circuits by connection across the rails in times of emergency.* |
| Up | The name in the report given to lines used by trains travelling in the direction of Manchester Victoria. |
| Wheelset | Two rail wheels mounted on their joining axle. |
| Worksite | The subdivision of an engineering possession that is delimited by boards with lights to show its entry and exit points within the possession. It is controlled by an engineering supervisor who manages the safe execution of work within it. |

## Appendix C - Key standards current at the time

| | |
|---|---|
| NR/L3/CIV/006/1C, Issue 4, 4 December 2010 | Handbook for the examination of Structures Part 1C: Risk categories and examination intervals |
| NR/L1/CIV/032, Issue 2, 5 September 2009 | The management of structures |
| NR/SP/CIV/084, Issue 1, April 2004 | Management of Existing Tunnels |
| NR/L2/OPS/021, Issue 3, 6 March 2010, (now superseded by NR/L2/OCS/021, Issue 4, 5 March 2011) | Weather – Managing the operational risks |
| NR/L2/TRK/001/A01, Issue 4, 5 December 2009 | Inspection and maintenance of permanent way – Inspection |
| NR/L3/TRK/1010, Issue 2, 26 August 2008 | Management of responses to extreme weather conditions at structures, earthworks and other key locations |
| Track Work Instruction 3G023, Version 1, March 2005 | How to manage cold weather |
| Track Work Instruction 3G024, Version 1, March 2005 | How to manage exceptionally low temperatures |

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