RAIB

Rail Accident Investigation Branch

Rail Accident Report

Partial failure of Bridge 94, near Bromsgrove, 6 April 2011

Department for Transport

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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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Summary

On Wednesday 6 April 2011, an assistant track section manager (ATSM) employed by Network Rail discovered a structure (Bridge 94, on the main line between Birmingham and Gloucester) supporting the track which he believed to be collapsing. He was on site to check a hole in the ballast under sleepers on the down main line, first identified during a routine track inspection eight days previously, which had reappeared despite being filled with clean ballast.

The ATSM arranged for track maintenance staff to attend site during the evening to monitor the track. They discovered that ballast was falling into a watercourse under each passing train, and reported the failure to Network Rail's fault control. Staff on site arranged an emergency speed restriction, followed by the diversion of trains onto other lines to bypass the failing structure. There were no injuries, but severe disruption continued until after emergency repairs were complete 36 hours later.

Nobody had inspected the part of the structure where the failure occurred since 2001 because neither Railtrack/Network Rail nor their structures examination contractor recognised the need for staff who were trained and equipped to enter a confined space to examine this structure. Consequently the condition of the part of the structure supporting the track was unknown.

The RAIB has identified one learning point from this incident: the importance of undertaking reconnaissance visits as an integral part of the planning process for detailed examinations.

The RAIB has also made recommendations to Network Rail that focus on improving the awareness of structures which are not easily visible from track level, and improving the structures examination regime.

Introduction

Preface

1 The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences.

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

Key definitions

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

4 Mileages on the Birmingham to Gloucester and Bristol route are measured from Derby. The terms 'up' and 'down' in this report are relative to the direction of travel. The up direction is north towards Birmingham and Derby, and the down direction is south towards Gloucester and Bristol.

5 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B. Key standards current at the time are referenced in appendix C.

The incident

Summary of the incident

6 At 19:27 hrs on Wednesday 6 April 2011, Network Rail track maintenance staff reported to Network Rail's fault control the discovery of a 'collapsed *culvert* in the *four-foot* of the down main line' at 55 miles 61.5 chains, between Bromsgrove and Stoke Works Junction in Worcestershire.

7 Approximately one hour later an assistant track maintenance engineer (ATME), who had arrived on site, applied to the signaller for an emergency speed restriction on the down main line. Subsequently, he arranged to divert down trains via the parallel down goods loop to protect the damaged structure. Trains were kept running at reduced speed until resources were on site to allow the structure to be examined. During the examination, all trains were stopped to minimise the risk of further collapse. The route remained partially or fully blocked until 07:00 hrs on Friday 8 April 2011.

Context

Location

8 Bridge 94 is located 0.35 miles (0.56 km) south of Bromsgrove station, on the Birmingham to Gloucester and Bristol route (Barnt Green to Westerleigh Junction via Dunhampstead).

9 Bridge 94 carries the railway over a shallow watercourse, Bromsgrove Stream, which flows from east to west at this location (figure 1).

Organisations involved

10 Network Rail owns and maintains the track and infrastructure, and employs the track maintenance staff who discovered the ballast loss and took action to prevent an accident occurring. Network Rail also employs structures maintenance staff including the structures maintenance engineer responsible for Bridge 94.

11 Owen Williams Railways was a structures examinations contractor, responsible for examining Bridge 94 between 1996 and 2006 initially for Railtrack, then for Network Rail from 2002. It employed structures examiners who undertook examinations on site and prepared reports, and examining engineers who reviewed these reports and made recommendations to Railtrack/Network Rail for maintenance actions.

12 Amey has been responsible for examining Bridge 94 since acquiring Owen Williams Railways in February 2006 and inheriting the structures examination contract. In May 2009, Amey was appointed to provide these services to Network Rail on a national basis under a new contract known as the 'Civil Examinations Framework Agreement' (CEFA).

13 Both Network Rail and Amey freely co-operated with the investigation.

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

Rail infrastructure involved

14 The railway infrastructure at this location comprises up and down main lines flanked by goods loops and sidings. Bridge 94 carries seven tracks and associated connections over Bromsgrove Stream, of which four are *running lines* in regular use (figures 2 and 3).

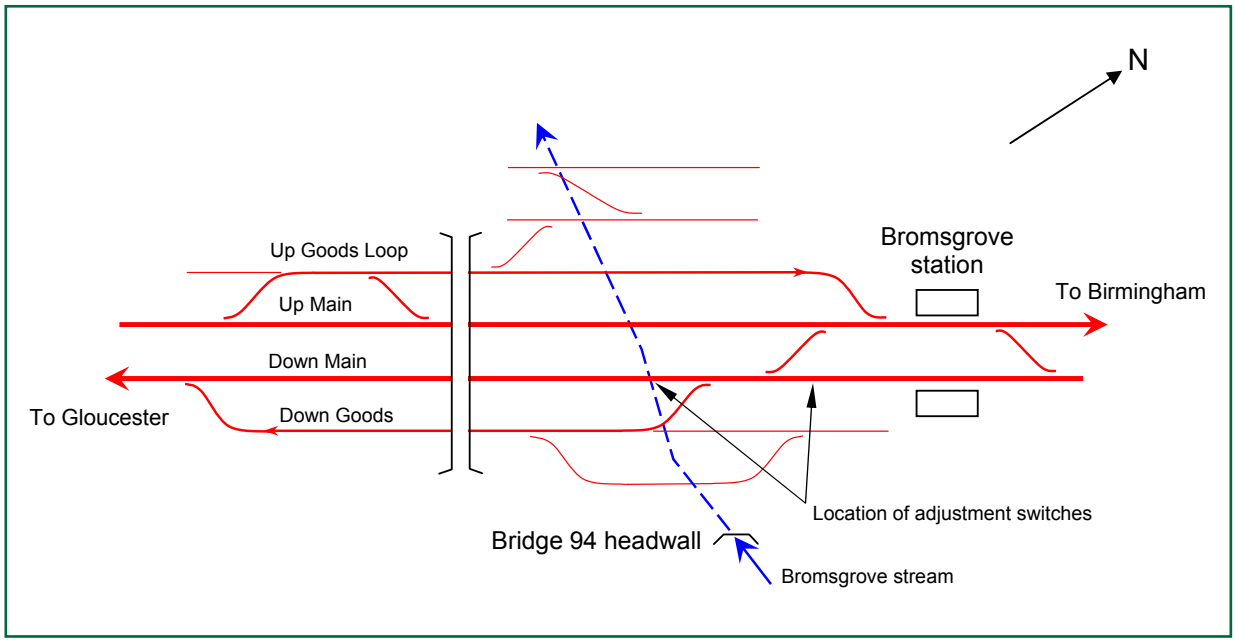

Figure 2: Schematic track layout diagram

Figure 3: Site overview following the incident looking north-east towards Bromsgrove station

15 The railway is not electrified, and has maximum permitted line speeds of 80 mph (129 km/h) on the main lines, 50 mph (80 km/h) on the down goods loop and 15 mph (24 km/h) on the up goods loop at this location. The main lines comprise *continuous welded rail* (CWR) on concrete sleepers, installed in 1970, and the loops comprise jointed track which has been welded into longer lengths on timber sleepers. The route has a *route availability* (RA) value of 8.

16 *Adjustment switches* are located on the down main line at 55 miles 53.5 chains and 55 miles 61.5 chains (figure 2). Their function is to provide an intentional gap in the rail, either side of *unstrengthened switches and crossings* (unstrengthened S&C), to isolate them from thermal expansion forces in a long section of otherwise unbroken rail. The adjustment switch at 55 miles 61.5 chains was installed at the same time as the CWR, and is supported on timber sleepers. It is located immediately above Bridge 94.

17 Bridge 94 is a single span *underbridge* carrying the railway over Bromsgrove Stream. The span between abutments varies between 1.76 metres and 1.9 metres, with an internal height above the surface of the water of between 1 metre and 1.4 metres. The width of the deck (ie length over watercourse) has not been accurately measured, but exceeds 47 metres, before connecting directly into a storm drain system beneath a modern housing estate on the west side of the railway. Network Rail considers the structure to be a bridge rather than a culvert because it has non-brickwork spanning elements and directly supports the track.

18 Bridge 94 comprises seven side by side decks. In a structural assessment report produced by consultants for Network Rail in August 2003, the decks are labelled A to G, commencing at the upstream end. Deck sections E and G are brick arches and the remainder are flat concrete decks dating from a partial reconstruction in 1931 which reused the original abutments (table 1).

Deck	Deck type	Width of deck section	Change in direction
A	Flat deck (bullhead rails)	2.1 metres	Straight
B	Flat deck (concrete filler beams)	13.1 metres	Straight
C	Flat deck (bullhead rails)	3.8 metres	19º to right
D	Flat deck (concrete filler beams)	2.1 metres	Straight
E	Brick arch	7.9 metres	Straight
F	Flat deck (concrete filler beams)	8.6 metres	6º to left
G	Brick arch	Over 10 metres *	Straight
	TOTAL WIDTH	Over 47 metres	

**Connects into storm drain*

Table 1: Bridge 94 schedule of decks

19 The structure changes direction at two locations. It is not possible to see through the structure from the upstream end, or to determine its course at track level. The downstream end is not visible from the surface.

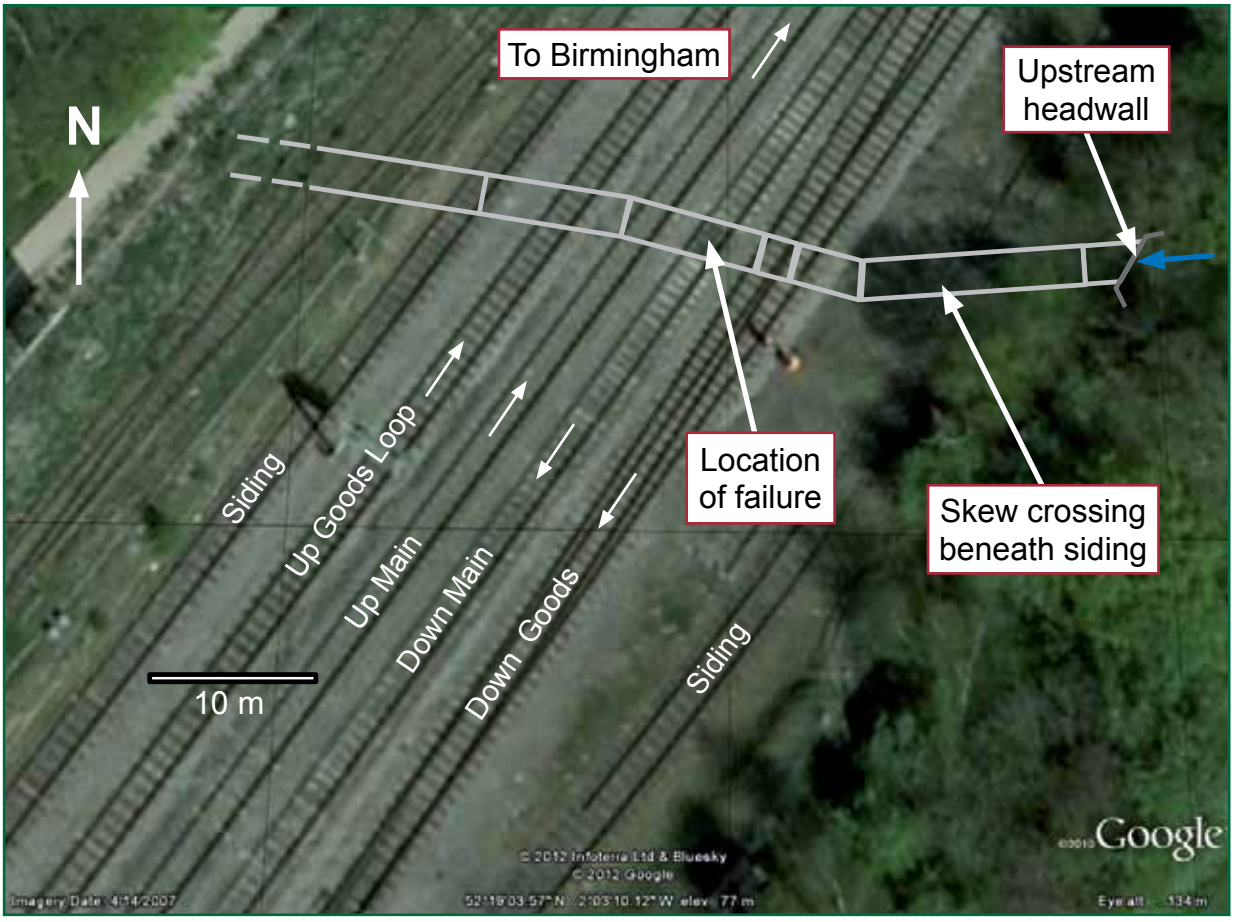

Figure 4: Overhead view showing approximate alignment of Bridge 94 relative to tracks (courtesy of Google Earth)

Figure 5: Upstream headwall with railway in background

20 Bridge 94's upstream headwall is located outside the railway boundary on the down (east) side of the railway in woodland (figure 5). The downstream end lies beneath a modern housing development (paragraph 17) and does not have a headwall.

21 Deck E, which partially failed on 6 April 2011, supports the down goods loop, the down main line and part of the up main line. It is a brick arch, 0.4 metres thick comprising 3 rings of brickwork. The crown of the arch is recorded as being 0.97 metres below track level.

Staff involved

22 The track patrollers and assistant track section manager (ATSM) who identified the defect during routine *basic visual track inspections* each had over 10 years experience. They were based at Network Rail's permanent way maintenance depot at Worcester, and reported to the Track Maintenance Engineer (Gloucester).

23 The ATME who went to site when the problem was discovered on 6 April 2011 was based at Gloucester. He had held this post since 2003, and had over 10 years track maintenance experience.

24 The structures examiner who undertook the *detailed examination* of Bridge 94 in March 1999 (refer to paragraph 65) had over 20 years relevant experience at the time of the examination, initially with British Rail, and then Owen Williams Railways. He worked within a pool of examiners based at Gloucester, but only went to Bridge 94 once.

25 The structures examiner who undertook the detailed examination of Bridge 94 in October 2005 (refer to paragraph 72) had five years experience at the time of the examination, and worked for Owen Williams Railways. He undertook one detailed examination and several *visual examinations* at Bridge 94 (refer to paragraph 55).

26 The examining engineer who reviewed and made recommendations on the 2005 detailed examination report had worked for Owen Williams Railways for five years as a graduate civil engineer. During this time, he had worked as an assistant examining engineer for 18 months. He became a full examining engineer approximately three months before he reviewed the report.

27 The Network Rail structures maintenance engineer who reviewed and signed-off the 2005 detailed examination report had been recently been appointed to the role. He had over 15 years experience as a structures assessment engineer.

Events preceding the incident

28 The first visual indication of a problem occurred on Tuesday 22 March 2011, when a patroller (Patroller A) undertaking a weekly basic visual track inspection reported that the adjustment switch on the down main line at 55 miles 61.5 chains needed lifting and packing with ballast. He indicated on his report form that this work was necessary within 4 weeks, and the work was entered into the depot's work plan for attention three weeks later.

29 The next basic visual track inspection took place on Tuesday 29 March 2011. Patroller A, who on this occasion was being mentored by the ATSM, observed a lack of ballast in the four-foot (ie the space between the running rails) beneath the same adjustment switch. He made a record on his patroller's report. The ATSM instructed the patroller to replenish the ballast, which he did. Despite having visited this site many times, neither member of staff was aware that there was a bridge beneath the track at this location.

30 On Tuesday 5 April 2011, during the following week's inspection, a different patroller (Patroller B) found that ballast was missing beneath the adjustment switch. He contacted the ATSM who instructed him to top up the ballast again. The ATSM also arranged to make a special inspection himself the following morning.

31 On Wednesday 6 April 2011, the ATSM observed that the void had reappeared, but saw no evidence of track movement when trains passed over the site. He examined the site, looking for manhole covers which might indicate the presence of a cross-track drainage pipe. He located the upstream headwall of Bridge 94 in the undergrowth on the east side of the railway (figure 5), and became concerned that the structure could be collapsing. He stayed on site to monitor the situation during the day, and arranged for a further inspection by Patroller B that evening. As there was no evidence of rail movement, he did not consider that a speed restriction was necessary at this time.

32 At 19:00 hrs that evening, Patroller B attended site with a colleague specifically to inspect the defect. They measured a depression 350 mm deep below bottom of sleeper level (figure 6) and one member of staff entered the structure and observed ballast in the watercourse (figure 7). Patroller B was concerned and contacted the Gloucester ATME and requested his attendance. The ATME was not on-call, but agreed to attend site and advised Patroller B to inform Network Rail's fault control and request a structures examiner.

Figure 6: Ballast loss beneath sleepers at adjustment switch (photograph courtesy of Network Rail)

Figure 7: View from within structure showing distortion of arch beneath down main line and ballast lost into watercourse (photograph courtesy of Amey)

33 The ATME arrived at 20:00 hrs and measured the track using a track gauge. He did not find any *static track geometry* faults despite the lack of ballast, but was sufficiently concerned to contact the signaller at Gloucester, and request an emergency speed restriction on the down main line of 50 mph (80 km/h) for passenger trains and 30 mph (48 km/h) for freight trains.

34 When the ATME was informed of ballast in the watercourse, he entered the structure and observed ballast falling into the water as a train passed above. He lowered the speed limit on the down main line again to 20 mph (32 km/h) for all trains pending the arrival of the structures examiner. Initially, this required signallers to caution all trains from Blackwell because of the steep gradient[1] immediately north of Bromsgrove station which could have made it more difficult for drivers to slow their trains sufficiently for the speed restriction at Bridge 94.

35 A structures examiner employed by Amey arrived at 21:00 hrs, and inspected the structure internally. He informed the ATME that the damage was severe. During a discussion which followed, the ATME stated that, in his opinion, any resultant failure of the structure would cause a train on the line above to derail at any speed. At the structures examiner's recommendation, the ATME blocked the down main line to all traffic. He also imposed a 20 mph (32 km/h) emergency speed restriction on the adjacent up main line and down goods loop.

Events following the incident

36 At 22:00 hrs, the ATME and structures examiner took part in a telephone conference with Network Rail structures engineers and operations staff. The structures examiner advised that a 600 mm square section of brick arch had failed. The conference supported the ATME's decision to block the down main line.

37 At 01:30 hrs on 7 April 2011, Network Rail staff had completed installing emergency speed restriction boards on the track.

38 Just before 05:00 hrs, all lines were blocked to permit a specialist structures examination contractor with diving equipment to enter the structure and undertake an internal inspection without the risk of loose material falling onto him.

39 At 05:47 hrs, the examiner advised that the damage appeared more widespread from below and was likely to affect the up main and down goods lines. He reported that the lower two of the three rings of brickwork forming the arch structure had separated from the upper ring (figure 8), that surrounding brickwork exhibited significant deformation to the arch profile suggesting possible widespread failure, and that the north abutment was leaning away from the watercourse (figure 9). A hole in the roof was allowing ballast to drop through.

[1] The Lickey Incline, a continuous 2.65% (1 in 37.7) gradient for two miles is located immediately north of Bromsgrove station, descending from Blackwell to Bromsgrove.

Figure 8: Loss of brickwork at location of failure (photograph courtesy of Amey)

Figure 9: Deformation to roof of deck E and leaning north abutment looking upstream (photograph courtesy of Amey)

40 Work commenced immediately to excavate the structure from above to confirm the exact location of the affected arch and adjacent unaffected decks relative to each track (figure 10). Following a review of the damage, the up goods loop was reopened to traffic at 08:28 hrs. The down loop was found to be only marginally affected, and a decision was taken to temporarily reinforce the track by screwing additional lengths of rail to sleepers. This allowed the down loop to reopen for passenger traffic at 16:50 hrs, with a 20 mph (32 km/h) emergency speed limit in place.

Figure 10: View into structure from track level following partial clearance of ballast (photograph courtesy of Network Rail)

41 Traffic was not restored on all four running lines until 8 April 2011 (with a speed restriction) once engineers had installed a semi-permanent structure over the top of the failed arch to support the track bed. During this period many trains were diverted via Worcester, Droitwich and Kidderminster. This caused disruption to both passenger and freight services.

The investigation

Sources of evidence

42 The following sources of evidence were used:

- witness statements;
- structure examination reports, including detailed reports from 1999 and 2005;
- structure assessment report (2003);
- Network Rail *track recording unit* (TRU) data;
- track patrollers' reports;
- Network Rail standards;
- site photographs and measurements; and
- a review of previous RAIB investigations that had relevance to this incident.

Key facts and analysis

Identification of the immediate cause[2]

43 **The line was in an unsafe condition because of the partial failure of an under-track structure.**

44 The severe distortion of the arch and loss of brickwork in the area known as 'deck E' meant that the structure supporting the down main line was in the process of collapsing when discovered. This caused the track formation to subside, although static track geometry was unaffected at the time that the failure was discovered.

45 The adjustment switch located above the structure formed a discontinuity in the rails, increasing the track's vulnerability to distortion as a result of vertical movement. The collapse of the structure would have created a significant derailment risk.

Identification of causal[3] and underlying factors[4]

Adjustment switch

46 **The roof of the structure was damaged by impact loading originating from train wheels passing over an adjustment switch which had been installed above, creating a minor, but recurring dip in the track. This was a causal factor.**

47 An adjustment switch is designed to provide a smooth transition between adjacent sections of rail by means of an angled (scarf) joint (figure 11). However, the lack of continuity in the rail can lead to a dip developing under train loading, causing passing trains to impart additional impact loads into the track formation and any buried structures. The phenomenon known as *ballast memory* means that faults can recur in the same location. Maintenance intervention is driven by track geometry considerations. For track with a maximum line speed of 80 mph (129 km/h), Network Rail's track maintenance standards require intervention when a dip angle reaches 40 *millirads*[5] (approximately equal to a dip of 10 mm measured over 1000 mm), or a vertical alignment (*top*) fault exceeds 19 mm[6].

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

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

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

[5] Network Rail standard NR/L2/TRK/001/A01 Inspection and maintenance of permanent way – Inspection. Issue 4, 5 December 2009. Appendix D.

[6] Network Rail standard NR/L2/TRK/001/C01 Inspection and maintenance of permanent way – Geometry and gauge clearance. Issue 4, 5 December 2009. Table 5b.

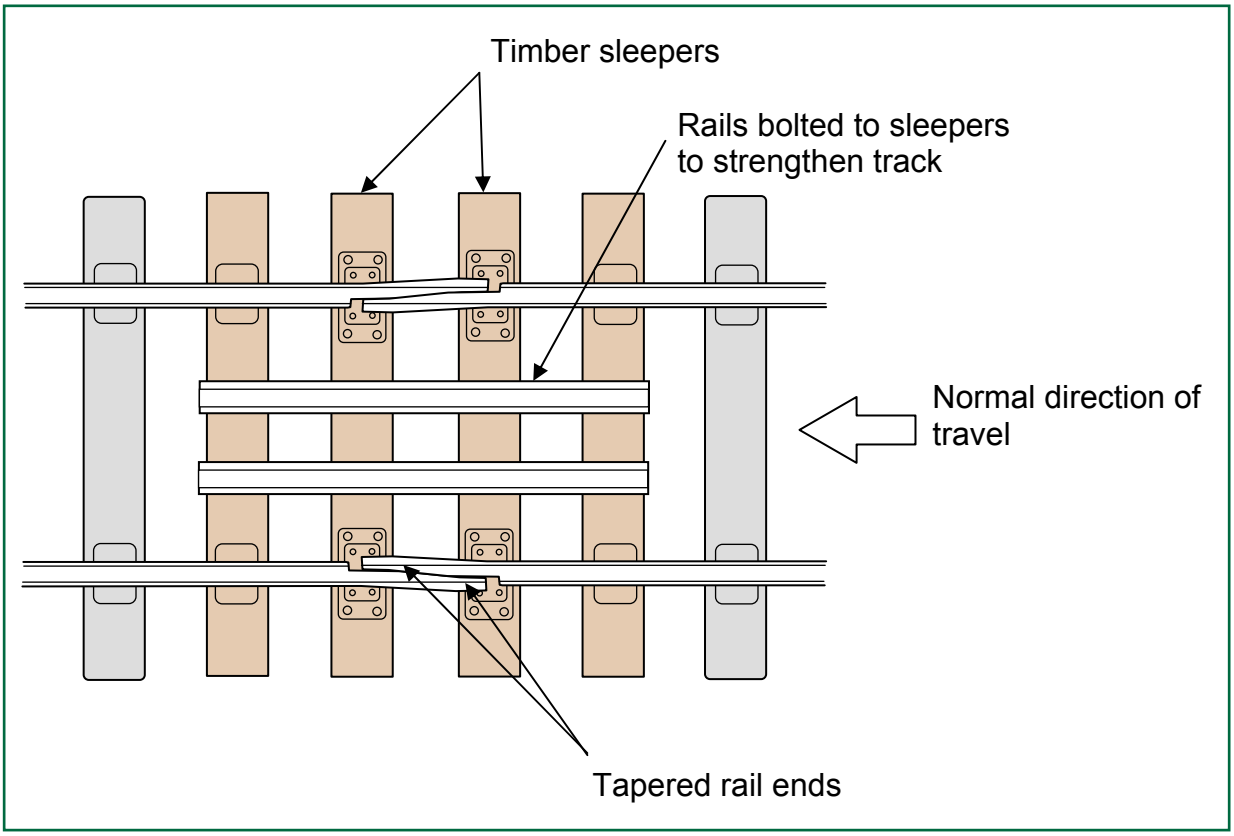

Figure 11: Diagram of an adjustment switch

48 Network Rail operates a TRU through Bromsgrove at approximately monthly intervals. Records of the *track geometry* obtained from TRU trains for the 12 months preceding the incident indicate that the adjustment switch on the down main line at 55 miles 61.5 chains had a tendency to dip, requiring periodic lifting and packing with ballast. It is recorded as a dipped joint on every TRU trace produced during this period.

49 On 3 June 2010, the TRU recorded a dip of 40.2 millirads on the right-hand rail which triggered a requirement for a visual inspection within 14 days and repair or replacement of the joint within 13 weeks. Network Rail staff responded by repacking the ballast underneath the adjustment switch to lift the joint and rectify the recorded defect.

50 On 10 February 2011 at the same location, the TRU recorded a variation in top of -20.62 mm on the right-hand rail. This exceeded the threshold of 19 mm and required maintenance intervention within 14 days. Again, Network Rail staff repacked the ballast underneath the adjustment switch, and data from the subsequent TRU run on 10 March 2011 indicates that the track geometry had been improved.

51 The adjustment switch required regular maintenance, but the level of intervention required was not significantly different from other adjustment switches and there was no early indication of a problem at this location.

Location of the adjustment switch

52 The position of the adjustment switch was dictated by the adjacent unstrengthened S&C. Standard NR/L2/TRK/3011 'Continuous Welded Rail (CWR) Track' states that 'S&C units that have not been designed to withstand the longitudinal forces produced by CWR shall be isolated by adjustment switches not more than 40 m distant'. The location of the adjustment switch, approximately 40 metres from the unstrengthened S&C unit, was compliant with this standard. However, there was some permissible flexibility in its position (ie it could have been moved closer), and it could therefore have been moved off the structure if the structure's position had been known.

Failure mechanism of the structure

53 The relatively shallow cover of one metre between the underside of the sleepers and the crown of the brick arch below meant that a significant proportion of the impact loading from train wheels passing over the adjustment switch was transferred into the structure below. While this was not desirable, Network Rail's structures examination regime should have been sufficient to manage the risk associated with impact loading arising from the position of the adjustment switch.

54 The most likely cause of the arch failure was a combination of the following factors:

a. Water ingress due to failed or absent waterproofing (refer to paragraph 85). This will have led to weakening of the mortar between the brickwork, increasing the tendency of the brickwork to flex when loaded and making it less able to resist movement. As the failure progressed, mortar was crushed and turned into a slurry, reducing the effective load carrying capacity of the individual arch rings.

b. Repeated impact loading from trains passing over the adjustment switch.

c. A lack of resistance from fill material behind the north abutment, which, when combined with a horizontal force that increased as the arch shape deteriorated, allowed the abutment to rotate outwards. As the arch widened and flattened, it is probable that it experienced a *snap-through-buckle* causing a sudden jump in deflection and dissipation of much of the horizontal (compressive) force.

d. The loss of shape and reduction in the compressive force allowed a section of the brickwork to fall out (figure 8).

55 At the time that the partial failure was discovered, the structure was substantially weakened and complete failure was probably imminent.

The structures examination regime for Bridge 94

Introduction

56 The purpose of Network Rail's structures examination regime is to establish and record a structure's condition, identify defects and provide sufficient information for management of its condition. This has been achieved by a programme of annual visual examinations and six-yearly detailed examinations, undertaken historically by British Rail staff, but since railway privatisation, by an examinations contractor. Recorded examinations for Bridge 94 are summarised in table 2.

Date	Type	Contractor	Comment
20/07/1978	Visual	British Rail	
1993	Detailed	British Rail	No record found
16/03/1999	Detailed	Owen Williams Railways	1 recommendation
18/11/2001	Inspection for assessment		For 2003 assessment report.
29/01/2004	Visual	Owen Williams Railways	
16/06/2005	Visual	Owen Williams Railways	
14/10/2005	Detailed	Owen Williams Railways	2 recommendations
08/06/2007	Visual	Amey	No record found
14/05/2008	Visual	Amey	
27/05/2010	Visual	Amey	

Table 2: Schedule of recorded examinations for Bridge 94

57 At the time of the 2005 detailed examination, Network Rail standard NR/SP/CIV/017 'Examination of bridges and culverts' mandated the examination process. The CEFA contract, introduced in 2009, has its own technical specification, but contains conditions derived from standard NR/SP/CIV/017 for bridges and culverts. In December 2009, standard NR/L3/CIV/006 'Handbook for the examination of structures' replaced standard NR/SP/CIV/017. However, Network Rail has not yet formally varied the CEFA contract to include standard NR/L3/CIV/006, and a derogation has been issued to Amey.

58 Under the CEFA contract, Network Rail produces a 'Task List for Examinations' in each contract year. For structures, the examination cycle begins in October/November when Network Rail sends Amey a provisional list of the structures which are to be examined the following financial year (1 April to 31 March). This list is finalised before the start of the financial year and includes the type of examination each structure is to receive. The examination process commences with planning of the site examination. An examiner is required to examine a structure and prepare a report with photographs, but does not make recommendations.

59 An examining engineer, working on behalf of the examinations contractor, reviews the examiner's report and uses professional judgement to recommend to Network Rail if work is required to maintain the structure. This judgement is guided by a risk matrix derived by Network Rail, and included within the CEFA contract specification. The examiner's report, with the examining engineer's review attached as a cover sheet, is submitted to Network Rail for consideration and possible action.

Visual examinations

60 **Examiners carrying out visual examinations were not required to enter the structure, and therefore this gave no opportunity to identify the condition of the track-supporting structure. This was a possible causal factor.**

61 The requirements for visual examinations are described in Network Rail's standards. Standard NR/SP/CIV/017 defined a visual examination as being:

> 'An examination to identify changes in the condition of a structure carried out from a safe observation location, without using special access equipment but using permanent access ladders and walkways, binoculars and hand held lighting where necessary.'

62 In the case of Bridge 94, examiners were therefore not required to enter the structure to undertake visual examinations since this was not deemed to be a safe location without using special access equipment. As a consequence, the visual examination reports produced for Bridge 94 (table 2) did not contain information on the condition of the structure beyond the upstream headwall (figure 5). There was no means for the examiner to identify problems above ground because the alignment of the structure was not marked at track level.

Detailed examinations

63 Detailed examinations, as laid down by standard NR/SP/CIV/017, required a close examination of all accessible parts of a structure, generally within touching distance, to produce a record that includes the condition of all parts of the structure. Although standard NR/SP/CIV/017 specified that 'culverts of sufficient size for person access shall be examined throughout', Bridge 94 had the following attributes which made access and examination difficult:

a. low headroom;
b. running water underlain by silt;
c. sinuous alignment;
d. long length over watercourse;
e. no access from one end;
f. lack of airflow and possible noxious fumes; and
g. multiple structural types of differing age, condition and characteristics.

64 Access to a *confined space* is governed by the Confined Spaces Regulations 1997 (SI 1997 no. 1713). Such spaces, by virtue of their enclosed nature, present a reasonably foreseeable specified risk. Under these regulations a 'confined space' has two defining features: firstly, it is a place which is substantially (though not always entirely) enclosed, and secondly, there will be a reasonably foreseeable risk of serious injury from hazardous substances or conditions within the space or nearby. Guidance published by the Health and Safety Executive states:

> 'You must carry out a suitable and sufficient assessment of the risks for all work activities for the purpose of deciding what measures are necessary for safety (The Management of Health and Safety at Work Regulations 1999, regulation 3). For work in confined spaces this means identifying the hazards present, assessing the risks and determining what precautions to take.'

Detailed examination – March 1999

65 Bridge 94 received a detailed examination in March 1999 by an examiner equipped with an oxygen meter and working with an assistant. The examination team was not correctly equipped to enter a confined space, and there was no appropriate working plan in place for work in a confined space.

66 The examiner's report, dated 16 March 1999, states:

> 'The examination was carried out from the down side, under the track formation to approximately the end of the Railtrack fence on the up side.'

Under the heading 'inaccessible parts', the report states:

> 'Due to lack of airflow I terminated the examination approximately under the boundary fence u/s' [up side].

The report also states:

> 'The watercourse is a confined spaces examination. I had to terminate the examination short of the up side end of the underbridge due to fumes and lack of air flow'.

67 These descriptions indicate that the examiner went right through the structure as far as the opposite railway boundary. However, his report does not include photographs of either arched deck, and in a section of the report which includes a generic list of structure parts, the examiner marked 'arch ring' with a dash to indicate that the feature was not present.

68 There is evidence that the examiner abandoned the examination when his oxygen meter indicated the presence of toxic fumes. His examination did not continue past the first bend, located 15 metres from the upstream headwall (paragraph 18) and therefore he did not observe the brick arch (deck E) supporting the main running lines. The lack of reference to an arch was because the examiner did not find it and was not aware it was there. The RAIB understands that the examiner used the preceding detailed examination report dating from 1993 for reference, but this record has now been lost.

69 While the examiner was correct to terminate the examination because he was not equipped to enter a confined space, his report is misleading and wrongly suggests that he had accessed the majority of the structure including the sections supporting the running lines. The report also contains a diagram which wrongly indicates that the structure is straight.

Review of the 1999 detailed examination report

70 The examining engineer who reviewed the examiner's report on behalf of Owen Williams Railways before it was submitted to Railtrack completed a cover sheet. He marked the question 'complete exam?' with 'Y' [yes]. This was a reasonable interpretation based on statements made in the examiner's report (ie the report states that the examiner had reached the opposite railway boundary). The examining engineer recorded that the upside end of the structure was not examined due to 'lack of access and presence of noxious fumes' which closely reflected the examiner's comments. The examining engineer made one recommendation regarding repointing the abutments.

Detailed examination – October 2005

71 **The detailed examination undertaken in October 2005 did not include an examination of the area which subsequently failed. This was a possible causal factor.**

72 Bridge 94 received its most recent detailed examination in October 2005 by Owen Williams Railways. The examiner entered a short distance into the structure before terminating his examination. His report states:

> 'The first 4m only from the downside could be examined due to the headroom being less than 4'. The upside was not located due to the housing estate.'

Under the heading 'inaccessible parts', the report states:

> 'Only the first 4m of the soffit could be examined due to the confined spaces and risk of toxic fumes, as well as the lack of headroom, to the downside end.'

Like the 1999 report, it makes no reference to the arch deck carrying the main running lines as the examiner was not able to access this part of the structure.

73 Network Rail standard NR/SP/CIV/017 states, 'Unless otherwise agreed with the structures manager, a reconnaissance visit shall be made to each structure before undertaking a detailed examination to identify any hazards associated with carrying out the examination'. There is no record of the structures manager, a Network Rail post, waiving the requirement for a reconnaissance visit prior to the 2005 detailed examination, but it did not take place. Instead, the manager responsible for planning this detailed examination for Owen Williams Railways decided that no reconnaissance visit would be necessary. This was normal practice at that time.

74 Owen Williams Railways' review of the 1999 report during the planning of this examination did not identify that Bridge 94 included a confined space, despite the statement made in that report (paragraph 66). As a consequence, no special arrangements were made to facilitate the 2005 examination. Although the examiner was trained to enter confined spaces, he did not have the necessary safety equipment with him, or a planned system of work appropriate for the task. It was therefore not possible for him to complete the task safely.

75 Neither Railtrack nor Network Rail, as infrastructure owners, provided their examinations contractors with information on specific hazards for each structure because a comprehensive record of hazards associated with each structure did not exist.

Review of the 2005 detailed examination report

76 The examining engineer who reviewed the 2005 examination report did not identify that additional resources were required to complete the task. The opportunity to identify whether remedial work was necessary was therefore missed, and this was a possible causal factor.

Examining engineer's review

77 An examining engineer employed by Owen Williams Railways reviewed the 2005 detailed examination report in October 2005, and prepared a cover sheet using a similar template to that used in 1999. He marked a box at the top of the form which asks the question 'Complete exam?' with a 'Y' (refer to appendix D).

78 To inform his review, the examining engineer consulted the 1999 detailed examination report to identify any significant defects or ongoing areas of concern. As this report does not mention the arch supporting the running lines or that the structure changes direction several times, he was unaware of the principal structural features (paragraph 67). Neither did he have access to the assessment report relating to the 2001 inspection (refer to paragraph 85). It is possible that the examining engineer did not recognise that the 4 metres examined (paragraph 72) represented less than 10% of the structure's length. Under a list of parts, the examiner had only marked the foundations and waterproofing as 'Ne' [not examined], and this may have misled the examining engineer.

79 Amey has stated that the 'Y' in the 'Complete exam' box was not intended to indicate that the report was complete, but rather to amend the record held on the database to show that it was to be the final report for that structure that year (ie there would be no follow up report covering parts not included in the current report, identified in the section titled 'Hidden parts not examined'). Under this heading, the examining engineer recorded 'visual examination only', and gave the reason as 'insufficient headroom'. He also made two recommendations for the removal of vegetation and repointing open joints in the abutments.

80 The document was submitted to Network Rail as a detailed examination report. By amending the record held on the database to show that there was no requirement for a follow-up report, the action of recording 'Y' in the 'Complete exam' box had the effect of circumventing the need for a properly conducted detailed exam during that six-yearly examination cycle.

81 The examining engineer had undertaken this role for less than two years at the time of reviewing the report (paragraph 26). He was aware that Network Rail engineers would review the report with his comments and recommendations, and believed that they would request a full examination if they considered that additional examination work was required. He would only reject a report if there was insufficient information to make a decision.

Structures maintenance engineer's review

82 Network Rail's structures maintenance engineer (SME) responsible for the Bromsgrove area reviewed the report and the examining engineer's recommendations in November 2005. He had had no previous dealings with this structure and reviewed the report without reference to other information. His review focused on the examining engineer's comments, and he noted that the examining engineer considered the report to be complete, without recognising that the major part of the structure had been omitted or the significance of this. The report made no mention of an arch and the SME had no way of knowing, based on the documents he had available during his review, that the primary track-supporting element had not been examined.

83 The SME signed off the report, accepting the examining engineer's statement that it was complete. He did not adopt either of the examining engineer's two recommendations on the basis that he considered this work to be minor and unnecessary at that time.

Structural Assessment of Bridge 94

84 Railtrack commissioned a structural assessment of Bridge 94 from an engineering consultancy in August 2001. Assessments are typically commissioned every 18 years for bridges, and involve the inspection and measurement of structural elements to facilitate calculations to determine whether the structure remains capable of carrying the required loads. At the time, the assessment process was managed separately from the examination regime due to the different technical disciplines involved and the large number of reports to be processed, and there was no policy of making assessment reports available to examination contractors.

85 Bridge 94 was inspected in November 2001 by staff trained and equipped to enter confined spaces (figure 12). Railtrack received the inspection report, which included photographs of the structure, in January 2002. The corresponding assessment report was delivered in August 2003, and confirmed that the structure was in 'fair condition' and sufficiently strong to carry the loads imposed by rail traffic. Deck E was found to have an acceptable arch shape, but the report recorded a 5 mm wide longitudinal crack from abutment to abutment and damp staining indicating that the waterproofing had broken down.

Figure 12: Internal photograph (November 2001) showing decks C, D and E (photograph courtesy of Network Rail)

86 The assessment report confirmed that the structure was sufficiently strong to carry the imposed loads from rail traffic, but recommended re-waterproofing the deck, monitoring and repointing of 5 mm cracks in the brick arch sections, replacing small areas of damaged brickwork and removing obstructions to water flow.

87 A Network Rail structures assessment engineer (SAE) reviewed the assessment report, and visited site in November 2004 to resolve anomalies he had observed on a drawing. He subsequently hand-amended the general arrangement drawing to put the tracks in the correct order.

88 He made recommendations in a memorandum to the Network Rail territory civil engineer dated 7 December 2004 for minor work including the replacement of missing bricks and removal of sediment to improve water flow. Normal practice was for the territory civil engineer to endorse the memorandum if he agreed with it, and forward it to the SME to take action.

89 The SME did not take action on receipt of the memorandum as the recommended work was not of an urgent nature, and he did not have sufficient information to develop a work instruction for a contractor to undertake. He decided instead to wait until he received the 2005 detailed examination report and consider both sets of recommendations together. However, when the SME came to review the 2005 examination report (paragraph 83), he omitted to reconsider the actions recommended in the memorandum.

Network Rail's knowledge of the structure

90 **Reference information available to Network Rail staff about Bridge 94 was poorly collated and inaccessible. This meant that judgements about the effectiveness of the examination regime and the structure's maintenance requirements were based on incomplete information. This was an underlying factor.**

91 The Network Rail SME was not aware that the down main line at Bromsgrove was supported on a brick arch as this information was not apparent from the detailed examination report. Had he been concerned and sought other documents to cross-reference against, he would have found that reports were unavailable, incomplete or inaccurate. The RAIB has been unable to find evidence of a compliant detailed examination for this structure at any time.

92 The ability of Network Rail's staff to oversee the activities of the examinations contractor was compromised by a lack of knowledge or information about the structure. This also precluded Network Rail from using its Structures Condition Marking Index (SCMI) system contained in standard NR/GN/CIV/041, designed as a high level asset management tool in order to measure and highlight the change in condition of its bridge stock with time. SCMI requires the production of drawings and labelling to provide a consistent approach to examining the whole asset, and standard NR/SP/CIV/017 required detailed examinations to obtain enough information for an existing SCMI sketch and for a definitive list of the elements of a structure to be checked.

93 There was no SCMI output for Bridge 94 because there was insufficient information available on the structure. However, this did not prompt Network Rail to investigate why this information was missing.

94 The examination regime was ineffective because the detailed examinations were incomplete and the examiners carrying out visual examinations were not required to enter the structure.

95 Evidence obtained by the RAIB suggests that, historically in this area, there has been a philosophy of treating the 'best-achievable' examination as complete. This unsatisfactory situation meant that incomplete examinations were sometimes accepted in circumstances where access was difficult and risk was perceived to be low without further risk mitigation being considered.

96 Following the incident on 6 April 2011, the Office of Rail Regulation identified that there was a problem with the way some examinations had been undertaken, and served an improvement notice on Network Rail (Western). This is discussed further at paragraph 115.

Factors affecting the severity of consequences

The position of the structure was not readily apparent

97 Staff responsible for track design and maintenance did not have access to a list of structures supporting the track, and the exact location of the structure was not identifiable at track level. These factors affected the potential severity of the outcome by delaying the identification of the cause of ballast loss and subsidence of the formation by track maintenance staff. It also denied maintenance staff the opportunity to identify the cause of the problem and relocate the adjustment switch away from the structure.

Observations[7]

Arrangements for the 2011 detailed examination

98 In December 2010, Network Rail issued Amey with a 'Task List' showing detailed examinations required to be completed between April 2011 and March 2012. This listed Bridge 94 as requiring a detailed examination by October 2011 (ie the sixth anniversary of the last detailed examination). The task list indicates that Bridge 94 is an underline bridge over a stream, but gives no information on other hazards or safe access arrangements.

99 Amey's senior delivery manager responsible for arranging examinations instructed his area delivery managers to review historical reports for structures in their own areas. The purpose of this review, known as a 'robustness exercise', was for the area delivery managers to identify structures where special access requirements were necessary (eg road closures, roped access, confined spaces etc), and to arrange reconnaissance visits where considered necessary in accordance with the CEFA contract.

100 The robustness exercise did not identify Bridge 94 as requiring a reconnaissance visit, or that special arrangements were necessary to permit confined spaces access. Amey has been unable to explain why this was missed as the 2005 report states that this structure has 'confined spaces and risk of toxic fumes' (paragraph 72). The oversight apparent during the planning of the 1999 and 2005 detailed examinations was perpetuated and it is probable, therefore, that an examiner arriving on site in October 2011 would have again been unable to complete the examination had the structure not failed in the interim.

101 Access issues, where identified by this process, are recorded on Amey's ALARM database which is used for the planning and processing of examinations. This will gradually increase the sum of knowledge available once all structures have been subject to a compliant detailed examination.

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

102 Although Network Rail (Western Route) provides its examinations contractor with advance notice of detailed examinations, it does not always advise them a full year before the examination is to take place. This denies the contractor the opportunity to undertake a reconnaissance visit at the same time as they undertake the annual visual examination. As a consequence, some reconnaissance visits do not take place due to the number of site visits and resources required.

The role of structures maintenance engineers

103 Network Rail's structures maintenance engineers are office-based and do not routinely gain first-hand experience of many of the assets within the geographical areas for which they are responsible. This makes it more difficult for an SME to identify errors or omissions in reports. The lack of independent checks of examiners' work was observed to be a factor in the RAIB's investigation into a retaining wall failure at Dryclough Junction in West Yorkshire (RAIB report 17/2011), for which a recommendation was made (refer to paragraph 121b).

Staff safety

104 Two members of Network Rail staff entered the structure during the evening of 6 April 2011 to identify the extent of failure. Although the RAIB acknowledges that this action was taken in an attempt to protect the safety of the railway, these staff may have put their own safety at risk without sufficient knowledge of the hazards involved. Network Rail has addressed this issue directly with the staff concerned.

Staff response to the initial incident

105 Network Rail staff responded diligently and promptly to the observed track defect even though it related to a bridge of which they were previously unaware.

Knowledge of surface water culverts and sewers passing under railway land

106 Surface water culverts and other water-carrying structures cross railway land at numerous locations throughout the United Kingdom. Ownership of these structures is divided between the railway infrastructure owner (eg Network Rail), water companies and other organisations (eg the Environment Agency). The structures range in size from 100 mm to 2000 mm in diameter. In the case of water company assets, legal agreements made when the railway was built put the liabilities on the railway unless the asset is newer than the railway in which case there will be a crossing agreement. This means that the water company has no requirement to inspect these assets unless this is required by the infrastructure owner.

107 Network Rail has limited information on culverts and pipes of 900 mm or less, as many of the records relating to these structures have been archived or lost, and the information is often missing from route plans, despite the fact that many are track-supporting. A study of structures crossing beneath the railway, undertaken by Thames Water for the London area in 2005, estimated that up to 70% of small brick culverts (350 mm to 750 mm diameter) were in very poor condition, and 50% of clay pipes (525 mm to 600 mm diameter) were in poor condition. Other assets were found to be in a reasonable condition. The presence of unidentified and/or unmarked structures presents an unknown risk to the safety of the operational railway.

Summary of conclusions

Immediate cause

108 The line became unsafe because of the partial failure of an under-track structure (**paragraph 43**).

Causal and underlying factors

109 The causal factor was:

- The roof of the structure was damaged by impact loading originating from train wheels passing over an adjustment switch which had been installed above, creating a minor, but recurring dip in the track (**paragraph 46, Recommendation 1**).

110 Possible causal factors were:

a. Examiners carrying out visual examinations were not required to enter the structure, and therefore this gave no opportunity to identify the condition of the track-supporting structure (**paragraph 60, Recommendation 2**).

b. The detailed examination undertaken in October 2005 did not include an examination of the area which subsequently failed (**paragraph 71, Learning point 1**).

c. The examining engineer who reviewed the 2005 examination report did not identify that additional resources were required to complete the task, and the opportunity to identify whether remedial work was necessary was therefore missed (**paragraph 76, refer to paragraph 121a**).

111 An underlying factor was that reference information available to Network Rail staff about Bridge 94 was poorly collated and inaccessible (**paragraph 90, Recommendation 3**).

Factors affecting the severity of consequences

112 A factor that exacerbated the consequences of the event was that:

- staff responsible for track design and maintenance did not have information on the location of undertrack structures (**paragraph 97, Recommendation 1**).

Additional observations

113 The process of identifying structures requiring special access arrangements, solely by reference to existing reports (ie without reconnaissance visits), has repeatedly failed to identify the confined space hazard at Bridge 94 (**paragraph 102, Learning point 1**).

114 In the course of this investigation, the RAIB has become aware of a study by Thames Water which has identified gaps in the management of water-carrying structures which pass under railway land. In some cases, Network Rail's knowledge of their location or condition is incomplete. This has led to damage occurring during track maintenance, tamping, drainage works, bank stabilisation or electrification work, and the lack of a maintenance programme for these assets (**paragraph 107, Recommendation 1**).

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

Improvement Notices issued by the Office of Rail Regulation (ORR)

115 On 13 May 2011, the ORR served an Improvement Notice on Network Rail (Western Route) after finding evidence of incomplete examination reports. In summary, this notice applied to structures and culverts and required Network Rail to:

- introduce a system to identify incomplete examinations;
- assess risks from incomplete examinations and take action to complete these.

116 In response to this Improvement Notice, Network Rail (Western Route) has undertaken an exercise to review the examination reports for all 5000 culverts and 4000 underbridges within the route. This review aimed to identify incomplete examination reports and structures where access is constrained making examination difficult. As a consequence, 3% of the culvert and 0.5% of the underbridge population were classified as high risk (ie those that supported the track where structures examinations were incomplete) and will be subject to further action. The study found no cases that were judged by Network Rail to present as serious a safety risk as Bridge 94.

117 On 20 May 2011, the ORR served an Improvement Notice on Network Rail nationally on the basis that Network Rail did not have 'suitable and sufficient measures in place for ensuring that non-earthworks structures are fully examined and reports of those examinations are evaluated at appropriate intervals to enable [Network Rail] to determine whether and to what extent remedial works are required to ensure that the structures remain capable of safely carrying the imposed loads; whereby rail users may be exposed to increased levels of risk to their safety'. The Notice included a schedule of six areas which the ORR required Network Rail to address. The issue of this Notice was in response to work undertaken by the ORR during 2010, and was not directly related to the incident at Bromsgrove.

118 Network Rail's response to the issues identified in the Improvement Notice has included further development of its structures examinations database (CARRS), which was first introduced in December 2008 and is used as an asset management tool to schedule examinations and as a maintenance database. The upgrade is intended to address weaknesses in data quality, caused by migration from different legacy systems, which had made it difficult for Network Rail to identify incomplete examinations. This will require decisions to be recorded, particularly where this relates to non-compliances (eg parts not examined). CARRS will also provide an electronic link to Amey's ALARM database to give users greater visibility of the status of reports. The ORR has accepted Network Rail's responses and closed the Improvement Notice on 30 November 2011.

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

119 Network Rail has repositioned the adjustment switch at 55 miles 61.5 chains to move it away from Bridge 94.

Learning point[8]

120 The RAIB has identified one learning point for the railway industry:

Network Rail should remind its examination contractor(s) of the importance of undertaking reconnaissance visits as an integral part of the planning process for detailed examinations, and consider whether it can assist by providing the list of detailed examinations in sufficient time to allow the examinations contractor(s) to plan accordingly. For example, consideration should be given to providing a list of forthcoming detailed examinations in time for reconnaissance to be undertaken concurrently with the previous visual examination (paragraphs 110b and 113).

[8] An issue which the RAIB wishes to draw to the attention of industry bodies and railway staff so that they can take appropriate action at their own discretion.

Previous RAIB recommendations relevant to this investigation

121 The following RAIB reports on previous occurrences are relevant to issues identified in this report. Recommendations which address factors identified in this investigation are listed, and are not remade so as to avoid duplication:

Failure of Bridge RDG1 48 (River Crane) between Whitton and Feltham on 14 November 2009 (RAIB report number 17/2010, published 23/09/2010)

The foundations of a Victorian bridge carrying the railway over the River Crane near Feltham in West London failed without warning, causing part of the bridge to subside. The underlying causes included the dependence of the examining engineer's review on the completeness of the bridge examiner's report.

Recommendation 3

Network Rail should re-consider the purpose of the role currently performed by the examining engineer and then identify the information and resources (including time) that are required to undertake the task effectively.

In an interim response dated 15/02/2011, Network Rail advised the ORR:

- it understood the concern regarding the adequacy of information available to the Examining Engineer from the examiner, and had discussed this issue with the contractor (Amey);
- Amey had improved its quality control processes and has responded to prompts and discussions on level of audit;
- Amey had increased its Examining Engineer resource and the percentage of examinations rejected by Examining Engineers has increased;
- the issue of quality control and assurance has been part of an independent audit into Network Rail's examination processes; and
- work to enhance the information management systems used by Network Rail will investigate the means to draw more complete information from Amey where such records exist.

The ORR reported on 05/10/2011 that it has concluded that Network Rail has taken the recommendation into consideration and is taking action to implement it. The ORR will report again in June 2012.

Derailment of a passenger train near Dryclough Junction, Halifax on 5 February 2011 (RAIB report number 17/2011, published 20/10/2011)

A lineside retaining wall failed causing rubble to fall onto the track which derailed a train. The investigation found deficiencies in the examination of the wall by Network Rail's examination contractor, and in the way in which Network Rail handled reports from the local authority concerning problems with the wall. The underlying causes included omissions in the examination reports produced by the examiner which were not identified by the examining engineer, and lack of independent checking of the examiner's work which is therefore vulnerable to the risk of error by omission.

Recommendation 3

In conjunction with its examination contractor, Amey, Network Rail should review the effectiveness of the existing structures examination regime and implement any changes found necessary. The review should include, as a minimum:

- consideration of why examiners do not always report persistent defects; and
- a consideration of whether the examination system should be enhanced to require supervisors and/or engineers to periodically inspect structures.

Network Rail is currently considering this recommendation and will provide a response to the ORR in due course.

Recommendations

122 The following recommendations are made in addition to those already made by the RAIB following previous investigations[9]:

1 *The purpose of this recommendation is to promote the improvement of asset knowledge and to assist asset maintainers and railway staff in identifying the location of structures on site.*

Network Rail should introduce a programme of marking the position of all track-supporting structures which are not apparent from the surface, so that their presence can be taken into account by those responsible for managing incidents, maintaining the railway, and designing and upgrading infrastructure (paragraphs 109, 112 and 114).

2 *The purpose of this recommendation is to address the risk arising from visual examinations being incomplete as a result of access constraints.*

Network Rail should review the ways in which it visually examines those structures which cannot be seen from a safe observation location and where access is constrained. This review should consider the ways in which effective examinations can be carried out, and where this cannot be achieved, alternative measures to manage the risk. Any necessary improvements to the examinations regime identified in the review should be implemented (paragraph 110a).

3 *The purpose of this recommendation is to enhance the information available to staff reviewing examination reports.*

Network Rail should improve reference information available to those responsible for reviewing structures examination reports, to enhance the accuracy and effectiveness of the report review and evaluation processes (paragraph 111).

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

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

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

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

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

Appendices

Appendix A - Glossary of abbreviations and acronyms

ALARM	(Amey's system for managing structures examinations)
ATSM	Assistant track section manager
ATME	Assistant track maintenance engineer
CARRS	Civil Asset Register and electronic Reporting System
CEFA	Civil examinations framework agreement
CWR	Continuous welded rail
PDI	Pre-detailed inspection (or reconnaissance visit)
S&C	Switch and crossing
SAE	Structures assessment engineer
SCMI	Structures Condition Marking Index
SME	Structures maintenance engineer
TRU	Track recording unit [train]

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.

Adjustment switch	An overlapping (scarf) joint installed in the rails at the junction of continuous welded rail (CWR) and jointed track, and between CWR and some switch and crossing units (S&C units) to isolate the adjacent track from longitudinal movement caused by temperature changes in the CWR.*
Ballast memory	A term used to describe the behaviour of track when the top returns to a previous state following track maintenance work. The underlying mechanism is due to differential settlement of the disturbed ballast.*
Basic visual track inspection	Regular check of the track and infrastructure for defects which could affect the safety of the railway or its reliable operation.
Confined space	A place which is substantially (though not always entirely) enclosed, and where there will be a reasonably foreseeable risk of serious injury from hazardous substances or conditions within the space or nearby.
Continuous welded rail (CWR)	Comprises rails welded together to form a single rail length over 37 m (120 ft).
Culvert	A structure with a span or diameter greater than 450 mm and less than 1800 mm whose primary purpose is usually, but not exclusively, to permit water or services to pass under or adjacent to a railway, road or other Network Rail infrastructure. Within Network Rail standards, the term excludes outside party pipelines.
Detailed examination	A close examination of all accessible parts of a structure, generally within touching distance, of sufficient quality to produce a record that includes the condition of all parts of the structure, the uses to which the structure is being put, recommendations for remedial action, and any other relevant facts.
Examining Engineer	The person responsible for managing examinations of a Structure or group of Structures. (RT/CE/S/047 Issue 3).
Four-foot	The area between the two running rails of a standard gauge railway.*
Headwall	Wall forming end of bridge deck.
Millirad	An angular measurement in thousandths of a radian. One radian is the angle subtended by an arc whose length is equal to its radius.

Route availability	A number which describes the effective loading a particular track or bridge can withstand, ranging from 1 (least) to 10 (most) at a particular speed.*
Running line	A track other than a siding over which running movements are made under the control of a main signal.*
Snap-through-buckle	A phenomenon which can occur in shallow arches when loading causes a sudden reversal of curvature over all or part of the structure.
Static track geometry	Track geometry measured in the unloaded state (ie no train present). See track geometry also.
Switch and crossing	Track consisting of switches and crossings forming connections between lines.*
Top	Describing the vertical alignment of a track over a short distance.*
Track geometry	The horizontal and vertical alignment of the track, including cant.*
Track recording unit	Rail vehicle equipped to measure and record track geometry.
Underbridge	A bridge that allows passage under the railway.*
Unstrengthened switches and crossing	Switches which have not been designed to transfer the thermal stresses arising from continuously welded rail (CWR) between the switch rails and stock rails.*
Visual examination	An examination to identify changes in the condition of a structure carried out from a safe observation location, without using special access equipment but using permanent access ladders and walkways, binoculars and hand held lighting where possible.

Appendix C - Key standards current at the time

NR/L2/TRK/001/A01	Inspection and maintenance of permanent way – Inspection
NR/L2/TRK/001/C01	Inspection and maintenance of permanent way – Geometry
NR/L2/TRK/3011	Continuous Welded Rail
NR/SP/CIV/017 issue 2 (April 2004) (formally RT/CE/S/017)	Examination of bridges and culverts
NR/L3/CIV/006 (replaced NR/SP/CIV/017 in Dec 2009 but not used within CEFA contract)	Handbook for the examination of structures
NR/GN/CIV/041 issue 3 (formally RT/CE/C/041)	Structures condition marking index handbook

Appendix D - Front summary sheet: 2005 detailed examination report

Network Rail

STRUCTURE EXAMINATION REPORT FRONT SUMMARY SHEET

EXAMINATION TYPE:- Detailed
ROUTE:- Birmingham and Gloucester **MILEAGE:-** 55M 61.5C

	ELR	GROUP	TYPE	NUMBER	EXAMINATION DATE	COMPLETE EXAM?	
STRUCTURE	BAG2	B	U/B	73232	14/10/05	Y	

NAME	Barlow deck, stone abutment underbridge	

HIDDEN PARTS NOT EXAMINED (EXCLUDING FOUNDATIONS)	PART	REASON NOT EXAMINED
	Visual examination only	Insufficient headroom

ITEM	COMMENTS & RECOMMENDATIONS BY THE EXAMINING ENGINEER	PRIORITY WITHIN YEARS	EST. COST £k +/- 20%	Extent	Severity	Probability	Risk Score
1	Remove vegetation from approach walls and repair as necessary	4	5	S	2	3	6
2	Rake out and repoint deep open joints to abutment	4	6	S	2	3	6
			11k				

The following must be done by the Examining Engineer for all detailed examination reports: (Tick box if applicable)

- Review changes to alignment for bridges over water & behaviour of watercourses: ☑
- Review red/amber/green classification & any local instructions, for bridges liable to be struck by road vehicles: ☐
- Review DTS category: ☑
- Review condition rating of structure for assessment prioritisation: ☐

Signed for Appointee	Print Name	Date
		26 October 2005

Section B: To Be Completed By Network Rail

ITEM	ACTION TO BE TAKEN	Code	EST £k	PRIORITY Year	Risk S	Risk P	Risk R.S
1,2	N						

Signed For Employer	Date	Database Updated	Date

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