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<td>Ballast</td>
<td>Crushed rock packed under and around sleepers to hold track in position, spread weight, and provide drainage.</td>
</tr>
<tr>
<td>Ballast Crib</td>
<td>The ballasted area between sleepers.</td>
</tr>
<tr>
<td>Bogie</td>
<td>A structure incorporating suspension elements and fitted with wheels and axles, used to support rail vehicles at or near the ends and capable of rotation in the horizontal plane. It may have two or more axle sets, and may be the common support of adjacent units of an articulated vehicle.</td>
</tr>
<tr>
<td>Data Logger</td>
<td>An electronic or tape recording data or event recording device fitted within rolling stock that is capable of recording certain information relating to the operation and movement of the rolling stock.</td>
</tr>
<tr>
<td>Down and Up Directions</td>
<td>Travel by rail away from Sydney is referred to as being in the Down direction. Conversely, travel towards Sydney is referred to as being in the Up direction. Travelling on a track towards Sydney, the right hand rail is termed the Down rail and the left hand rail is termed the Up rail.</td>
</tr>
<tr>
<td>Gauge</td>
<td>The distance between the inside running (or gauge) faces of the two rails, measured between points 16 mm below the top of the rail heads.</td>
</tr>
<tr>
<td>Kilometrage (km)</td>
<td>The track distance measured from the buffer stop at No. 1 Platform in Sydney Terminal (Central Station).</td>
</tr>
<tr>
<td>Network Control</td>
<td>The function responsible for managing train paths and issuing occupancy authorities.</td>
</tr>
<tr>
<td>Pumping</td>
<td>Sleeper movement where the sleeper moves up and down as rail traffic passes over it. This movement often results in the degradation and contamination of the ballast structure or can result from the same.</td>
</tr>
<tr>
<td>Network Control Officer</td>
<td>A Train Controller for an unattended location, a Signaller for an attended location, or a delegate carrying out some functions of a Train Controller or Signaller.</td>
</tr>
<tr>
<td>Rail Vehicle Detection System</td>
<td>A signalling system that uses continuous track-circuiting or axle counters to detect the presence of rail traffic in a block, and to prevent following or opposing entry into occupied blocks.</td>
</tr>
<tr>
<td>Stress Free Temperature (neutral temperature)</td>
<td>The temperature at which the rail is neither in tension or compression.</td>
</tr>
<tr>
<td>Three-pack / Two-pack</td>
<td>Three permanently coupled wagons / two permanently coupled wagons.</td>
</tr>
<tr>
<td>WOLO</td>
<td>A strategy for mitigating risk associated with hot weather is the imposition of speed restrictions when air temperatures of 38°C and above are forecast. This is referred to as applying WOLO speed restrictions. In most circumstances, the speed restriction is a reduction in the allowable train speed of 10 kph.</td>
</tr>
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EXECUTIVE SUMMARY

At approximately 1413\(^1\) on 28 November 2012, Pacific National coal service NB942 derailed the last six wagons on the Coxs Creek Bridge near the township of Boggabri. NB942 consisted of 71 loaded coal wagons which were being hauled by three locomotives at the front of the train. The train was travelling from Narrabri Coal to Port Waratah near Newcastle where it was to be unloaded.

The majority of the train had passed over the Coxs Creek Bridge when it experienced an automatic emergency application of the train’s brakes. Upon investigation, the crew found the last six wagons had derailed, with five of the six toppling off the bridge and spilling their payload. The last (sixth) of the derailed wagons remained in a precarious upright position on the bridge.

There were no personnel injured as a result of the derailment. All of the derailed wagons were damaged beyond economical repair. The bridge was extensively damaged with 130 metres of track destroyed as a result of the incident. The line was reopened to rail traffic on 20 December 2012 following major partial reconstruction of the bridge.

The wagons derailed due to a lateral misalignment which formed under one or more of the last six vehicles in the consist of train NB942.

The lateral misalignment resulted from track not being able to contain a build up of excessive compressive forces in the rail primarily due to:

- errors being made completing track stability calculations
- creep in the rails not being controlled
- the track infrastructure being in generally poor and variable condition
- inappropriate lifting of a speed restriction
- the track leading up to the bridge not being maintained to the applicable engineering standards.

The bridge was repaired and normal traffic resumed within a month of the derailment. The Australian Rail Track Corporation (ARTC) subsequently completed a planned project to significantly upgrade and strengthen the track between Gunnedah and Turrawan (near Narrabri).

\(^1\) All times referred to in this report are in Eastern Daylight-saving Time (UTC+11 hours).
ARTC is continuing to implement and train staff in a track stability management planning process which had been approved for roll out in July 2012. The process demonstrates a risk based approach to the issue of track stability management and requires plans to be developed by the person responsible for the relevant section of track for subsequent review and approval by the delivery manager for the area.

The ARTC has expressed confidence that full implementation of the track stability management planning process will adequately address the need for a more responsive and effective track maintenance regime, together with a more active and rigorous management oversight of maintenance planning and activity.

In view of the remedial action in progress, it is recommended that the ARTC develops a comprehensive audit program to test the achievement of the track stability planning process against the objectives for which it was designed, and initiates the audit once the track stability planning process has been fully implemented.
PART 1  FACTUAL INFORMATION

Introduction

1.1 At 1413 on Wednesday 28 November 2012, a Pacific National loaded coal service NB942 travelling from Narrabri Coal to Port Waratah (Newcastle) derailed the last six wagons on the Coxs Creek Bridge on the outskirts of Boggabri (see Figure 1). The three locomotives and the first 65 wagons of the train cleared the bridge with the leading locomotive coming to a stand at kilometre 511.

1.2 The last six wagons of the train had derailed with five of the six derailed wagons toppling off the bridge and spilling their payload. The last (sixth) of the derailed wagons remained in a precarious position on the bridge with its contents still contained within the wagon.

1.3 The coal wagons were all NHBH type wagons and were coupled in a three-pack format. There were no personnel injured as a result of the incident. All of the six derailed wagons were uneconomical to repair. The bridge was extensively damaged and 130 metres of track was destroyed. The line was reopened to rail traffic on 20 December 2013 following major bridge partial reconstruction work.

![Source: Google Maps](image1)

Figure 1: Map of incident location
Location

1.4 The derailment occurred on the Coxs Creek Bridge on the single line section of the track between Werris Creek and Moree. The bridge is approximately 1km from the southern outskirts of Boggabri, a small township in the north western region of NSW (see Figures 1 and 2).

Train Information

1.5 Coal train NB942 was owned and operated by Pacific National, a division of Asciano Limited. The train was hauled by three 82 class locomotives (8255, 8227 and 8242). The train was hauling 71 loaded NHBH coal wagons consisting of 23 three-pack combinations and one two-pack combination. Each wagon had an estimated gross mass of approximately 100 tonnes. The train measured 1256.7 metres in length and had a gross weight of approximately 7496 tonnes (including locomotives).

1.6 The derailed wagons were the last six wagons of the train consist. These wagons comprised of two coupled three-pack combinations. The three-pack wagons were permanently coupled together with drawbar couplings (see Photograph 1 right) while both ends of the rake had standard automatic knuckle coupler arrangements (see Photograph 1 left).
Photograph 1: Photograph 1 left, knuckle coupler and photograph 1 right drawbar coupler

**Track Information**

1.7 The track at Boggabri is a standard gauge (1435 mm) Class 1 track consisting of 53 kg/m continuously welded rail (CWR). The rail is fastened to steel and timber sleepers which are laid in a 1:1 pattern of timber and steel sleepers, using dog spikes for timber sleepers and spring fasteners for the steel sleepers. The track is further supported by a bed of stone ballast. The track is part of the network which ARTC leases and maintains. The section leading to the point of derailment is on a falling 1 in 90 gradient and becomes level at the bridge (see Figure 3).

![Figure 3: Curve and gradient diagram](Source: ARTC)
1.8 The rail safeworking system for the single line Emerald Hill - Boggabri - Werris Creek rail section is a Rail Vehicle Detection System.

**Bridge Information**

1.9 The Cox Creek Bridge is a single track bridge approximately 156 metres long built in 1970. It consists of 13 plate web steel girder spans with the rail supported on timber transoms (see Figure 4). It incorporates a walkway for use by maintenance staff.

![Figure 4: Coxs Creek Bridge schematic](source: ARTC)

**Train Crew Information**

1.10 The train crew consisted of a driver and co-driver, both of whom were Pacific National employees from the Gunnedah Depot. The crew members were within their respective medical and competency assessment periods and were familiar with and qualified for the route. Following the incident, the train crew were tested for the presence of drugs and alcohol. The tests returned with a negative result.

**Before the Derailment**

1.11 The crew members signed on at the Pacific National Depot at Gunnedah at 0700 on Wednesday 28 November 2012. They took charge of empty coal train NB941, a return service from Carrington, at Curlewis from where they departed at 0742. The crew travelled from Curlewis to Narrabri colliery where the train was loaded with coal. At the loading point the train number changed from NB941 to NB942.

1.12 After loading, the train departed Narrabri at 1247. On approach to Boggabri the crew noted another Pacific National train, NB139, standing in the loop waiting to cross with NB942. As they passed, the crews conducted a ‘roll-by’
inspection of each other’s train in accordance with standard procedure. No visible faults or anomalies with either train were detected in the process of completing the roll-by. The crew of NB139 added that they did not detect any audible faults as NB942 passed through.

The Derailment

1.13 The driver stated that as the leading locomotive approached the Coxs Creek Bridge, the train was travelling at approximately 76 km/h, that he was utilising dynamic braking to control the train and that the track appeared to be ‘normal’.

1.14 As the driver of NB942 approached km 515.750, he disengaged dynamic brake and utilised the throttle, increasing power to the 8th throttle notch position to maintain speed. At km 513.280 the driver reduced the throttle from the 8th to the 5th position. At km 513.250 he negotiated from 5th to 4th and then 4th to 1st position. Based on the data logger records, it is estimated that at this point, the lead locomotive was in the approximate location of the impending derailment (km 513.000).

1.15 The driver then moved the throttle from the 1st to the idle position. As the lead locomotive continued over the bridge, the driver re-applied power moving the throttle to the 1st, 2nd, the 3rd position. At this stage the 66th wagon reached the derailment point. The driver negotiated from the 5th to the 6th position and almost immediately, at 14:13:40, the brake pipe air pressure began to reduce resulting in an automatic application of the train brake. The driver reduced the throttle to the 4th position then moved it back to the 5th position, further reducing to the 3rd position and then returning to the idle position. Seconds later he moved the throttle to the 2nd then 3rd position and finally to the idle position.

1.16 The train came to a stand with the lead locomotive positioned at approximately 511 km. The crew initially thought that an air hose had failed, so the driver instructed the co-driver to walk to the rear of the train to locate the cause of the automatic train brake application.

1.17 At the 30th wagon position the co-driver found an air leak which he rectified. As it was apparent that the leak wasn’t significant enough to apply the brakes automatically, he continued on towards the rear of the train. When he arrived
at the 65\textsuperscript{th} wagon he noted that the air tap was in the open (downward) position and everything appeared to be normal. At this point he thought he was at the rear of the train. However, he then noted that the end of train marker was not visible and that the wagon number did not match with the number on his train consist form for the last wagon.

1.18 As he continued on, the co-driver noticed a fire in the distance and could not see any other wagons due to the smoke. He immediately informed the driver of the situation. As he continued further along the track he observed that there was extensive damage to the bridge and that six wagons were derailed with five of the wagons having toppled off the bridge and the sixth wagon remaining on the bridge in a precarious position (see \textit{Photograph 2}).

\begin{figure}
\centering
\includegraphics[width=\textwidth]{photograph2.jpg}
\caption{Co-driver's viewpoint when walking back}
\end{figure}

1.19 The network controller had visibility of the position of other trains on his control system and, in accordance with standard practice, blocked signals appropriately to ensure that NB942 was protected from other trains.

\section*{After the Derailment}

1.20 Now aware of the derailment, the co-driver also noted that the NSW Rural Fire Service was already in attendance and was trying to extinguish the fire. The co-driver immediately contacted the driver who in turn contacted the Pacific National Gunnedah Shift Supervisor. The co-driver concurrently
1.21 At the same time NSW Police arrived and took control of the scene. They then interviewed and breath tested the crew.

Injuries and Damage

1.22 There were no injuries to personnel as a result of the derailment but there was extensive damage to the bridge structure and 130 metres of track was destroyed. The six derailed coal wagons were ultimately scrapped as they were uneconomical to repair. There was no damage to the locomotives or the 65 wagons which remained on track.

Deployment

1.23 OTSI was notified of the incident at 1510 on 28 November 2012 and two investigators deployed to conduct an examination of the site and to commence preliminary investigations the following morning.

Environmental Conditions

1.24 At 1430 on 28 November 2012, the temperature recorded at Gunnedah, approximately 32 kilometres to the SSE of the incident site, was 33.9°C. The maximum had been 36.5°C and the minimum 18.5°C. At 1430 at Narrabri, approximately 43 kilometres to the NNW, the temperature was recorded as 32.7°C. The maximum had been 34.8°C and the minimum 20.6°C.

1.25 At the time of the derailment NSW was experiencing heatwave conditions similar to the record-breaking conditions of 2009. In the preceding 6 days, the maximum daily temperature in Gunnedah had exceeded 30°C including 37.8°C on 22 November, the hottest day of the month. Over the 6 days, the lowest temperatures had increased daily from 13°C to a high of 18.8°C on 27 November. Narrabri temperatures were similar in pattern and magnitude.

1.26 The crew reported that the weather was fine at the time of the derailment although 6.8 millimetres of rainfall was recorded at Gunnedah and 16.4 millimetres at Narrabri on 27 November 2012.
PART 2 ANALYSIS

Introduction

2.1 The investigative process was hampered by the conditions experienced on site. It was not possible to gain access to all areas within the derailment site due to the extent of damage to the bridge and rolling stock, and the danger posed by wagons suspended some 10 metres above the ground (see Photograph 3). To overcome these constraints, the damaged wagons and sections of bridge structure were moved off site to be examined in more detail.

![Photograph 3: Wagon suspended on bridge](image-url)

Train Management

2.2 The crew stated that immediately before the derailment they were travelling at approximately 75 to 76 km/h. Downloads from the data loggers on the three locomotives revealed the train was travelling at 76 km/h. From the downloads it was also verified that the driver had just gone from the 3rd throttle notch position into the idle position. The posted track speed for freight trains at the location was 100 km/h but loaded NHBH wagons were restricted to 80 km/h.

2.3 The investigation found no evidence that the crew operated the locomotives in other than a competent manner. No actions on their part are considered to have caused or contributed to the derailment.
Fatigue

2.4 An examination of the rosters of the crew members for the preceding two weeks revealed no evidence that would indicate fatigue or related human factors issues played a part in the derailment.

Environmental Conditions

2.5 In very hot conditions it is common for rail temperature to exceed the ambient temperature by 20-30°C and retain residual heat from the previous day. If exposed to an extended period of high ambient temperatures, rail temperatures can reach 70-80°C. The rail temperature at the site of the derailment could feasibly have been approaching such temperatures given the extant heatwave conditions. The rail would therefore have been experiencing high compressive forces wherever thermal expansion was being resisted.

2.6 The Gunnedah Basin is an area well known for its rich black soil which provides the formation on which the track is constructed. A significant characteristic of black soil is its swelling and shrinking in response to changes in moisture content.

2.7 In February of 2012 the area experienced a record wet period. This was followed immediately by a significantly dry period which continued beyond November. The consequent extremes of swelling and shrinking would have had a detrimental effect on the track geometry in the area over time.

2.8 Rail is designed to be in a stress-free condition at a particular temperature, i.e., it is neither in tension or compression. The rail in the area of the derailment was installed at the stress free temperature (SFT) of 35°C.

2.9 The maximum temperatures in the general area varied between about 30 and 37°C in the fortnight leading up to the derailment. In such conditions the rail would have retained heat and over time the temperature would have built up to well in excess of the nominal SFT. The rail at the derailment location would experience a compressive force of approximately one tonne per ºC above the SFT. Thus, the rail would have been well under compression at the time.

2.10 ARTC Engineering Standard ETM-06-07 Managing Track Stability – Timber Sleepered Track provides for the imposition of speed restrictions when air temperatures are forecast to exceed the specified levels ("WOLO conditions").
However, in accordance with ARTC standards, WOLO conditions were not required to be declared on the day of derailment.

**Wagon Loading**

2.11 The weights of all the wagons that remained on track were checked to ensure that the batch loading process at Narrabri had been correctly set and that the train wasn’t traversing the section between Narrabri and Port Waratah over the permitted axle loading. The weight report from the Newcastle Coal Infrastructure Group (NCIG) verified that the NHBH wagons were being operated within permitted loading constraints.

**Wagon Doors**

2.12 Opening of wagon unloading doors while on the move has caused derailments in the past. The NHBH wagon door mechanism was examined but found to be of a failsafe design: the doors can only be unlocked by a mechanism at unloading points. An inspection of the one kilometre leading up to the bridge did not reveal any sign of coal that might indicate an unloading door had opened accidentally. Therefore, wagon door failure was eliminated as a possible factor in the derailment.

**Wagon Journals**

2.13 The presence of a fire can often be a telltale sign of a screwed journal because of the heat generated in the failure of the component. No evidence of a screwed journal was identified. Although the incident site was difficult to access, it was possible to account for all axles and journals off the derailed wagons. The kilometre of track leading up to the point of mount was also checked for any signs of bearing or wagon components. None was found.

**Wagon Inspection**

2.14 The investigation was initiated on 29 November 2012 with an inspection of the locomotives and all the wagons that remained upright and on the track. The derailed wagons were inspected to the greatest extent possible within the limits dictated by the site and then photographed for future reference. A thorough inspection of the locomotives and standing wagons did not reveal any defects or anomalies that might have contributed to the derailment.
2.15 The bodies of the derailed wagons and their associated components were recovered to a location on the outskirts of Werris Creek. Most of the wagons were positioned upside-down to facilitate a thorough examination of the underside of the wagons (see Photograph 4).

![Photograph 4: All six derailed wagons located near Werris Creek](image)

2.16 The wagons were examined in detail by investigators and rolling stock experts on 18 December 2012. All major individual components were accounted for and examined for signs of fatigue and/or failure. They included:

- wheels
- axles and journal bearings
- bearings and their housings
- radial pads and housings
- unloading doors (bomb bay design) and their locking mechanisms
- springs
- brakes and brake rigging.

2.17 All components were found to be within specification and allowable wear tolerances. In particular, no anomalies were found in wheel profiles. It was concluded from the examination of wagon components that there was no
evidence indicating wagon component failure caused or contributed to the derailment.

**Coxs Creek Bridge**

2.18 The bridge was completely inaccessible at the time of the preliminary investigation, so bridge components from the damaged spans were taken to an ARTC site near Gunnedah where they could be inspected in detail (see *Photographs 5 and 6*). No evidence of pre-existing damage, deterioration or fatigue was evident. All damage appeared to have been caused in the derailment.

2.19 An examination of undamaged components indicated the bridge and its track were structurally sound pre-derailment. Structural steel members were in good condition and well maintained. Timber transoms on the bridge and their securing bolts were in good condition. Pandrol clips were used to fasten rail along the length of the bridge while dog spikes were utilised to secure the heavy check rails which were positioned in both UP and Down directions. However, Pandrol clips were not used to secure the extensions of the check rails to the track beyond the line of the abutments.

2.20 An examination of ARTC’s bridge maintenance records showed the bridge had been regularly inspected in accordance with their current Engineering Code of Practice ETE-09-01 *Structures Inspection*. An engineering inspection was required every 72 months with the next one due as at 31 October 2015. A visual examination was required every 24 months with the next one due as at 30 December 2013.
Track Examination

2.21 The point of mount (POM) was identified from marks on the Up rail as being at 513.002 km, just prior to the bridge (see Photograph 7). Further marks indicated the point of derailment (POD) was only two metres beyond the POM at 513.000. Such a short travel is indicative of a derailment caused by a buckled rail or acute curvature within a track. Significant scuff marks on the adjacent Down rail were consistent with the progress of a derailment.
A close examination was conducted of the one kilometre of track leading up to the POM. The ballasting was found to be generally inadequate. In several places the track anchors were not all hard up against the sleepers. Evidence of previous maintenance work was observed where anchors had been removed and had not been replaced or had not been positioned hard up against the foot of the rail. However, no evidence was found of wheels abrading, climbing or mounting the rails.

From a standing position approximately 50 metres prior to the derailment site a slight buckle could be seen in the track layout. Also of significance were voids in the ballast on the Up rail or eastern side of the track. Such voids are a telltale sign of lateral movement consistent with buckling of the track.

Some months after the derailment, OTSI was provided with a photograph taken very shortly post-incident. It showed voids within the ballast notably around the ends of the timber sleepers on the Up rail at the derailment site (see Photograph 8). These voids were far more prominent than when investigators inspected the site. This raises a concern that the site may have been inadvertently disturbed by human traffic before investigators arrived.
2.25 Immediately on notification of the incident, OTSI quarantined the site giving specific instructions that no-one was to touch or examine the site until investigators arrived. In incidents like this, it is imperative that the track and surrounding infrastructure and any vehicles or components of vehicles involved are not disturbed or otherwise interfered with. When OTSI investigators arrived they saw evidence that people had been walking on and around the track. A demarcation barrier had been erected, but served mainly as a warning of the risk of falling off the bridge or its abutment. This experience demonstrates the critical importance of securing incident sites and compliance with quarantine instructions until investigators arrive on site.
Ballast Profile

2.26 Ballast provides the means by which sleepers are kept in position and by which the loads on the track are transferred from the sleepers through to the formation. According to ARTC standards, approximately 60% of track stability can be attributed to the integrity of the sleepers and ballast.

2.27 As a heavy haul (Class 1) track, the nominal ballast depth should have been 300 mm in accordance with Table 4.1 in Section 4 of ARTC’s Engineering Code of Practice. Measurements taken over the 10 metres leading up to the bridge revealed a range of depths between 200 and 270 mm. Further, ARTC ballast profile documentation recorded depth deficiencies of 42 mm within 10 metres of the bridge and just prior to the POM.

2.28 Ballast within sleeper cribs was observed as being generally approximately 40 mm below the top of the sleepers. Many of the steel sleepers utilised to hold gauge were only around 70% full of ballast. This is particularly concerning with anchorage issues as the ballast does not contact the underside of the steel sleepers, resulting in reduced adhesion between the sleepers and the ballast.

2.29 ARTC welded track stability analysis (WTSA) reports recorded that the ballast was foul in both 2011 and 2012 but no action was taken to rectify the situation.

2.30 No records could be found to show that the ballast profile had been restored to the Code of Practice standard. Consequently, deficiencies in the ballast profile and condition would have been contributing to a deterioration in track stability.

Track Stability

2.31 The maintenance of continuous welded rail (CWR) track is complex in that there are high levels of co-dependency among track components. Any deficiencies in components will affect the strength and rigidity of the track as a whole and must be detected early and corrected quickly to prevent further deterioration of the track infrastructure.

2.32 To inform maintenance schedules and repair priorities, the ARTC undertakes regular assessments of the stability of sections of track in the form of welded track stability analyses (WTSA). The greater the loss of stability, the greater
the propensity for track to buckle (misalign). Stability is calculated in accordance with ARTC’s Engineering Standard ETM-06-07. It is based on the assessment of stability loss due to:

- rail adjustment (CWR should be in the correct adjustment at the stress free temperature (SFT))\(^2\)
- rail anchor condition
- ballast deficiencies
- track disturbances such as from, for example, resleepering and ballast maintenance
- track condition (includes consideration of the formation, sleepers and track geometry)

The sum of the individual assessments provides a ‘preliminary stability assessment’.

2.33 A ‘final stability assessment’ is then established by adjusting the preliminary assessment to take into account loss of stability due to ‘location factors’ unique to each 500 metres of track. These factors include curvature, grade, braking zones, directional working and bunching points such as level crossings, bridges, crossovers, and changeover of fastening types.

2.34 ARTC Engineering Standard ETM-06-07 (Part 2) states that a location with a stability loss of 55% or greater ‘requires immediate attention or evasive action’. A location with a loss between 40% and 55% ‘requires programmed attention or evasive action’ including speed restrictions when the ambient temperature exceeds 25 ºC.

2.35 While the WTSA is a very important tool it does have limitations. For example, it does not take into account:

- the effects of loose or missing fastenings
- the density of steel sleepers interspersed with timber sleepers
- loss of ballast or degree of compaction within steel sleepers
- the fouling of ballast
- re-distribution of stress caused by spot tamping.

2.36 A WTSA completed in August 2011 for the segment of track from 513.000 km to 513.500 km resulted in an estimated cumulative stability loss of 41%. A

\(^2\) The current SFT for track is 38°C, although in the past the previous standard specified 35°C; therefore, currently in NSW the SFT of some tracks is still set at 35°C.
WTSA for the same segment of track undertaken in September 2012 established the preliminary stability assessment as a loss of 46%. After adjustment, the final stability assessment resulted in a reduction in the loss to 10%. This reduction appears to be attributable to:

- rail creep not being taken into consideration
- no allowance being made for the intention to tamp sections of the track
- the changeover of types of rail fastenings at the bridge (bunching point) not being taken into account
- no allowance for ballast deficiencies which had been measured.

2.37 The track specialist with the Office of the National Rail Safety Regulator (ONRSR) recalculated the 2012 stability assessment using ARTC’s information and data. The individual loss assessments were as follows:

- tangent creep: 63% (based on uncorrected creep from 2011 and 2012 and addition of 15 mm to each rail)
- ballast deficiency: 24% (based on laser measurement and photographic evidence)
- anchor condition: 4% (based on uncorrected creep and photographic evidence)
- track disturbance: 24% (based on works orders and resurfacing records)
- track condition: 4% (based on worst Track Condition Index)
- special track conditions (based on reported poor formation, foul ballast, and disturbed ballast associated with steel sleepers): 30%
- location factor: a 1.1 multiplier (based on bunching point at bridge end).

The result was a stability loss of 163.9%, significantly in excess of the ‘immediate attention’ threshold of 55%.

2.38 ARTC argued that some of the calculations in this stability assessment were debatable. The ONRSR track specialist then recalculated several key components allowing for ARTC’s assertions that the track adjustment in 2011 was appropriate and correct, that the creep marks had not been re-set, that laser measurements in relation to ballast profiles were not valid and that photographs taken were distorted. The resultant stability loss amounted to 68.2%, made up of the following revised individual loss assessments:

- tangent creep: 4%
- ballast deficiency: 0%
• anchor condition: 4%
• track disturbance: 24%
• track condition: 0%
• special track conditions: 30%
• location factor: a 1.1 multiplier (bunching point).

The track clearly met the criteria for requiring ‘immediate attention or evasive action’ including the imposition of speed restrictions when the ambient temperature exceeded 25 °C.

2.39 Track stability management plans have been introduced by ARTC. They are designed to supplement pre-existing systems and constitute a process to draw together all the elements of track stability that were contained in a number of elements in the Code of Practice. They allow a track manager to apply local knowledge to establishing risk mitigation strategies for particular areas of concern. The vicinity of the derailment would have been an appropriate site for the preparation and implementation of such a plan.

2.40 Guidance for the development of track stability management plans ‘to specify tailored local requirements for managing lateral stability’ is contained in ARTC Engineering Standard ETM-06-07. Training in the preparation, review and application of the plan process was progressively rolled out across the network following approval in July 2012.

Creep

2.41 Track creep is the longitudinal movement of rail through the fastening system. It can be induced over time in a number of ways, including the forces involved in the braking or acceleration of rail vehicles and/or the effect of a majority of laden trains travelling in the same direction, as was the case at Boggabri. Various aspects of track structure may also contribute to the development of creep, e.g., improperly consolidated formation, poor quality and/or inadequate ballast, poor quality sleepers and inadequate or ineffective fixing of rail to sleepers.

2.42 The effect of creep is to increase compressive stresses in rail when the rail temperature exceeds the SFT. Where rail is constrained at a bunching point the effect is analogous to pushing a flexible steel rod increasingly harder against an irresistible barrier: the rod will eventually bend.
2.43 The maintenance team manager responsible for the Boggabri area stated there had been no creep in the vicinity of the derailment in the previous two years. However, creep had been recorded in the Up direction on the approach to Coxs Creek Bridge in conjunction with the WTSA in 2011 and 2012 (see Figure 5).

<table>
<thead>
<tr>
<th>Date</th>
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<th>Down Rail</th>
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<td>10</td>
<td>10</td>
</tr>
<tr>
<td>15/08/2011</td>
<td>513.500</td>
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</tr>
<tr>
<td>15/08/2011</td>
<td>514.500</td>
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<td>18</td>
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</tbody>
</table>

Figure 5: Measures of creep in vicinity of the Coxs Creek Bridge

2.44 The WTSA result for 2011 was largely due to the creep. To counteract the creep in the Up direction at 513.500 km it was appropriate to undertake an adjustment process whereby excess rail was removed. An adjustment process was completed on 28 September 2011 and recorded on a welder’s ‘Weekly Return - Aluminothermic Welding/Adjustment’ form. This record shows, instead of the removal of excess rail, 15 mm of rail had been inserted. Adding the additional rail would have the equivalent effect of reducing the SFT of the rail to 26ºC. Rail temperature above the SFT induces compressive forces in the rail in the order of one tonne per degree.

2.45 The WTSA undertaken 12 months later in August 2012 recorded no creep in the vicinity of the POD. However, more importantly, there had been creep into the section again just 500 metres prior to the POD at km 513.500. Given the integral rigidity of the bridge track structure, it is most likely the situation had resulted in the creation of a bunching point in the vicinity of the POD and
bridge abutment. No adjustment action was taken to counteract the creep recorded in 2012.

2.46 Given the nature of traffic on the line, it would be reasonable for creep to occur and create a need for regular planned maintenance. Daily freight services (such as NB942) routinely run loaded in the ‘Up’ direction and empty in the ‘Down’ direction, creating what is referred to as a ‘rolling pin’ effect. Train masses differ generally in the order of 7000 gross tonnes loaded in the Up direction and between 500 and 1000 gross tonnes unloaded in the Down direction.

2.47 This risk is somewhat reduced when traffic travels in both directions. Section 8.2.10 of ETM-06-07 discusses the calculation of the “Location Factor” for WTSA analysis – bidirectional and unidirectional are identified elements in Table 10. Although the WTSA has provision for adjustment for unidirectional working, there is none for bidirectional working.

2.48 Originally, the line was used predominantly for the transport of grain. With the development of the coal industry in particular, annual tonnages carried on the line increased markedly, especially since the commissioning of the Narrabri Colliery in 2009. In 2006 the annual tonnage carried amounted to some 4,300,000 tonnes; by 2012 this had increased to 11,200,000.

2.49 Although the WTSA has provision for adjustment for unidirectional working, there is none for bidirectional working. However, there is arguably some justification for taking it into account given traffic patterns of the nature of those existing on the incident line.

Track Maintenance

2.50 Keeping the track structure strong and rigid begins with the maintenance of a well drained, full depth and full width profile made up of well-graded sharp ballast. The ballast, in turn, must firmly contain high quality sleepers with tight-fitting, preferably resilient, rail fastenings. The rail must also be kept on its designed alignment and prevented from creeping.

2.51 ARTC has published standards and procedures for the construction, inspection and maintenance of track throughout its network. Engineering Standard ETE-00-03 Civil Technical Maintenance Plan sets out the policy for routine inspection of civil infrastructure in terms of mandatory inspection tasks
and minimum inspection frequencies. The policy is intended to mitigate the risk of buckles and requires defects to be either repaired immediately or within a specified period depending on their severity. Alternatively, they may be monitored and managed through the application of speed restrictions and/or load limits.

2.52 The most critical of the factors that can lead to a buckle in CWR is stress within the rail and it is the most difficult to detect. One of the key responsibilities for ensuring that track is maintained in a balanced state is the monitoring of creep. ARTC has specific policies and procedures for the management of track creep.

2.53 A number of different types of mandatory track inspections are conducted at varying time intervals. Principle among these is the inspection which is undertaken on a biannual basis utilising an AK Car. It provides:

- information on track in numerical data and graphical form
- a rating of the ride quality of the track
- the locations where track geometry parameters exceed allowable limits together with detail of the severity of the exceedences.

The information and data acquired is used to inform maintenance programs and decisions about appropriate temporary speed restrictions to be imposed in the interim.

2.54 An examination of the maintenance records and the AK Car recordings for the derailment site for the previous four years revealed serious flaws in top, twist, line and superelevation. The situation had deteriorated progressively between January 2009 and May 2012.

2.55 Track is normally tamped once every two years to assist in maintaining alignment by repacking the ballast around the sleepers. However, in the vicinity of Coxs Creek, there had been more than a normal amount of tamping activity (see Figure 6). The track in the immediate vicinity of the derailment had been tamped four times since July 2009, the last occasion being a week before the derailment (highlighted in Figure 6).
Because tamping disturbs a track, it is a general rule to apply speed restrictions while the track beds down. Such restrictions are maintained for the lesser of seven days or until approximately 100,000 tonnes of traffic have traversed the tamped section. This process can be eliminated by the use of specialised equipment but this was not the case at Coxs Creek.

No speed restriction was applied when the tamping was completed the week before the derailment. On the contrary, an existing 40 km/h speed restriction at the site was lifted.

**Mechanism of Failure**

The first part of the train traversed the track and onto the bridge without incident at a speed of 76 km/h. Under normal conditions, as locomotives and wagons travel over a track, there is a natural disturbance as the rolling stock loads and unloads the track creating a ‘precession wave’ as illustrated in Figure 7.
2.59 The distance between bogies on an individual NHBH wagon is approximately 13 metres. Significantly, within this span a ‘central wave’ is created which is an area of reduced resistance where the track unloads. As the train proceeded onto the bridge, the cyclic loading and unloading of the track continued.

2.60 The rails were under high compression due to the combined effects of creep and of being close to a bunching point. The general track geometry was less than optimum, the ballasting was below standard and the allowable track speed was probably higher than advisable in the prevailing conditions.

2.61 Eventually the track could no longer contain the stresses and maintain its integrity. At its weakest point, on an unloading cycle, the track moved laterally approximately 200mm to the Up (eastern) rail side. This rapid shift in the track created a very tight curve which the train could not negotiate. Engineering calculations indicate a train would need to travel at no more than 15 km/h to negotiate such a curve safely. This is far less than the posted speed and the speed at which train NB942 was travelling.

2.62 The next bogie to reach the acute buckle could not negotiate it. The leading Up side wheel mounted the rail head (POM) and travelled for approximately two metres with the wheel set running on the top of the rail head. It then abruptly fell off the rail (POD) with the Up side wheel flange landing on the 3rd Bridge.
(wooden) sleeper from the bridge and then striking the 2\(^{nd}\) (steel) sleeper dislodging the rail from it.

**Subsequent Sequence of Events**

2.63 A probable sequence of events was determined using measurements taken at the derailment site and observations during the inspection at Werris Creek of the damage sustained to the underside of each wagon.

2.64 Either the No.2 bogie of the 67\(^{th}\) wagon or the No 1 bogie of the 68\(^{th}\) wagon mounted the Up rail at kilometrage 513.002 initially. Both wagons then derailed pulling the 66\(^{th}\) wagon off the track with them as they were joined in a three-pack configuration with solid drawbar couplers (see Figure 8). At some stage they then also defeated the check rails, the primary defence against rolling stock coming off the bridge.

<table>
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<td>43083</td>
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<tr>
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<td>42728</td>
</tr>
<tr>
<td>71(^{st})</td>
<td>NHBH</td>
<td>42573</td>
</tr>
</tbody>
</table>

*Figure 8: Wagon pack configuration (Red is first three pack, blue second three pack)*

2.65 The derailed bogie travelled onto the bridge causing significant damage to the first five transoms. From the sixth transom onwards the transoms were shattered in the process of the derailment. As the first wagon toppled off the bridge it became entangled with the Up rail and dragged the rail off the bridge with it onto the ground below. As a result of this action, the Up rail was placed under significant tension which had a straightening effect on the track in the vicinity of the POM and POD.

2.66 The three-pack was attached to the wagons before and after it by knuckle couplers. These readily uncoupled allowing the three-pack to topple off the
bridge and onto the ground. Momentum allowed the following three-pack to continue forward until the 69th wagon was roughly level with the 68th. The 71st wagon broke away as it was entangled in the web of damaged bridge superstructure and brought to rest, remaining on the top of the bridge. The 69th wagon then toppled off the bridge and onto the 68th wagon while the 70th wagon was stopped abruptly and fell back on an angle to the ground (see Figure 9 and Photographs 9 and 10).

![Figure 9: Relative positions of the derailed wagons](image)

![Photograph 9: Positions of derailed wagons](image)
Speed Restrictions

2.67 Track managers are often required to implement track speed restrictions. There are various reasons for doing so. It may be simply to allow for track observation or to mitigate risk such as that associated with geotechnical anomalies, severe faults within the track or the inability to readily rectify maintenance issues.

2.68 Various lengths of track in the general area of the derailment, sometimes overlapping, had experienced multiple speed restrictions for varying lengths of time over at least the preceding five years. The restrictions were recorded as imposed primarily for ‘track geometry’, ‘rough ride’ or ‘geotechnical’ reasons.

2.69 Throughout 2012 the speed restrictions were varied on a number of occasions between 30 and 40 km/h. A limit of 30 km/h between kms 512.000 and 513.500 was imposed on all categories of trains on 11 January 2012 for ‘geotech formation problems’. It appears to have been lifted in mid-March.

2.70 In May 2012 the track AK charts revealed that there were serious flaws within the track infrastructure which were reaching specified exceedences in relation to the posted track speed for the section of track. As a result of these findings the information was relayed to the ARTC track managers. To mitigate the risk
of derailment they immediately imposed a 40 km/h speed restriction on all traffic including Xplorer trains which can travel at 120 km/h over the section.

2.71 On 3 July 2012 a further speed restriction of 40 km/h was placed on the section of line for the same reasons as those given on 11 January. Then on 18 September 2012, a Priority 1 exceedence was issued for the same area. Because of the level of the exceedence, a speed restriction of 30 km/h was posted. It was subsequently changed to a 40 km/h temporary restriction.

2.72 One week prior to the derailment, the 40 km/h temporary speed restriction was lifted despite tamping having been conducted just prior to the derailment location on the day beforehand. ARTC standards stipulate that a temporary speed restriction is to apply for a minimum of seven days or 100,000 tonnes of traffic must traverse over any section of track that has been tamped, whichever is the lesser. This is more imperative with heat conditions.

2.73 Following the conduct of a desktop certification involving a review of data input from a contractor’s certificates, the track manager completed a visual inspection of the site and deemed it to be suitable for normal speed operations. The track manager lifted the speed restriction in the belief that a programmed run over the track by a dynamic track stabiliser had actually occurred. It had not. The machine had broken down and he did not become aware of that fact until after the derailment.

2.74 Further investigation revealed that there was no robust process to ensure that the team manager or track maintenance personnel had visibility of the operations of the dynamic track stabiliser within the area. Additionally, track maintenance personnel were not fully conversant with the process of applying and removing speed restrictions.

Remedial Actions

2.75 As at the beginning of December 2013, ARTC had made a number of significant changes to the rail infrastructure at the location of the incident.

2.76 During the post-incident recovery phase, the track was reinstated and the bridge structure reconfigured to allow resumption of rail services. The longer term plan for the reinstatement of the bridge is being reviewed.

2.77 Further, ARTC initiated and has subsequently completed a project to install concrete sleepers with associated resilient fastenings, improved ballasting of
the track and restressing of the rails from Gunnedah to Turrawan. This
followed identification in 2010 of a need to strengthen the track structure
because of the implications of the increase in traffic. It was subsequently
budgeted and commenced shortly after the derailment.

2.78 At the time of the derailment, track stability management plans were in their
infancy. ARTC reports there continues to be revision of the plans and
procedures as the plans and associated training are rolled out. The process
demonstrates a risk-based approach to the issue of track stability
management. The plans are developed by the person responsible for the
relevant section of track and subsequently reviewed and approved by the
delivery manager for the area. They are reviewed in April after the summer
period and again in August prior to the onset of the next summer.

2.79 ARTC reports seeking alternative, simpler methods of measuring stress-free
temperature and having type-approved two methods which require limited
disruption to the track and interruption to rail services. The improvement in
the level of applied technology should result in the acquisition of more
accurate data to inform track stability management planning.
PART 3 FINDINGS

Causation
3.1 Pacific National coal service NB942 derailed as a buckle formed in the track under it as it traversed the track in the vicinity of kilometrage 513.002.

Contributing Factors
3.2 The buckle resulted from track not being able to contain a build-up of excessive compressive forces in the rail, primarily due to:

- incorrect calculation of track stability which masked a significant deficiency that would have alerted track maintainers to a situation requiring ‘immediate attention or evasive action’
- with the exception of one incorrect adjustment, creep being allowed to remain uncontrolled
- with the exception of the bridge, the track infrastructure being in generally poor and variable condition
- the track leading up to the bridge abutment not being managed as a bunching point
- the lifting of a speed restriction in association with spot tamping of the track nearby.

Other Findings
3.3 There was no evidence to suggest that the train’s vehicles, train management, the bridge condition or train drivers contributed in any way to the derailment.
3.4 There was no evidence showing that the track was upgraded or was subject to more intensive maintenance in response to the significant increase in tonnage on the line over the preceding six years.
3.5 Although the line had been subject to a significant number of speed restrictions, at the time of the derailment, the opportunities that became available were not taken to impose or increase speed restrictions on the basis of any one of WOLO, track and geotechnical conditions, maintenance delays and nearby spot tamping.
3.6 There was evidence to suggest that the site may have been disturbed inadvertently by human traffic prior to the arrival of investigators despite it having been quarantined.
PART 4 RECOMMENDATIONS

The investigation identified the need for a more responsive and effective track maintenance regime, together with more active and rigorous management oversight of maintenance planning and activity. The Australian Rail Track Corporation has expressed confidence that full implementation of the track stability management planning process will adequately address these issues. Since this significant remedial action is in progress, it is recommended that the Australian Rail Track Corporation develops a comprehensive audit program to test the achievement of the track stability planning process against the objectives for which it was designed, and initiates the audit once the track stability planning process has been fully implemented.
PART 5 APPENDICES

Appendix 1: Sources and Submissions

Sources of Information
- Australian Rail Track Corporation
- Bureau of Meteorology
- Independent Transport Safety Regulator
- Pacific National Pty Ltd

Submissions
The Chief Investigator forwarded a copy of the Draft Report to the Directly Involved Parties (DIPs) to provide them with the opportunity to contribute to the compilation of the Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and to submit recommendations for amendments to the Draft Report that they believed would enhance the accuracy, logic, integrity and resilience of the Investigation Report. The following DIPs were invited to make submissions on the Draft Report:

- Australian Rail Track Corporation
- Independent Transport Safety Regulator
- Pacific National Pty Ltd

Submissions were received from all three DIPs. The Chief Investigator considered all representations made by DIPs and responded to the author of each of the submissions advising which of their recommended amendments would be incorporated in the Final Report, and those that would not. Where any recommended amendment was excluded, the reasons for doing so were explained.