Australian Government
Australian Transport Safety Bureau

Derailment of freight train 6BM9

Creighton, Victoria on 21 January 2019

ATSB Transport Safety Report
Rail Occurrence Investigation (Systemic)
RO-2019-003
Final – 16 December 2020

Photo source: Chief Investigator Transport Safety (Victoria)

This investigation was conducted under the *Transport Safety Investigation Act 2003* by the Chief Investigator, Transport Safety (Victoria) on behalf of the Australian Transport Safety Bureau.

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Publishing information

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, ACT 2601
Telephone: 1800 020 616, from overseas +61 2 6257 2463
Accident and incident notification: 1800 011 034 (24 hours)
Email: atsbinfo@atsb.gov.au
Website: www.atsb.gov.au

Addendum

Page	Change	Date

Safety summary

What happened

On 21 January 2019, freight train 6BM9 was to travel from a logistics terminal in Barnawartha in northern Victoria to Altona, in Melbourne. The train consisted of two locomotives and 31 freight wagons. The train departed Barnawartha at about 1400 and travelled in a south-westerly direction through Wangaratta, Benalla and Euroa.

At 1530, the train passed through Creighton travelling at about 100 km/h. About 0.5 km after crossing Creighton Siding Road, the leading bogie of the third-last wagon derailed. The wagon derailed a short distance before a rail bridge. The train was brought to a stop with minor damage to the wagon and track, and no injuries.

What the ATSB found

The ATSB found that the wagon probably derailed as a result of the lateral misalignment of the track. The track misalignment was not evident to the locomotive crew when the train entered the location and developed under the dynamic loading of the train.

The track misalignment was probably primarily the result of track lateral instability. A mud hole at the derailment location had resulted in poor ballast support of sleepers, reducing the track's resistance to movement. A combination of this degraded support and compressive forces within the rails created conditions for track instability. The longitudinal compressive forces were due to the hot conditions of that day, and possibly localised low stress-free-temperatures in the rails near the rail bridge.

The Australian Rail Track Corporation's (ARTC) systems for managing track lateral stability did not lead to the location being managed as a special location potentially vulnerable to instability. Although the reduced ballast profile at the mud hole had been identified and monitored in accordance with the ARTC code of practice, more significant levels of response were available to manage the risk of instability. These included repair or imposing a temporary speed restriction when temperatures reached a predetermined limit.

What has been done as a result

ARTC advised that its Track Stability Management Plan (TSMP) for the section containing Creighton has been reviewed. As a result, the 2019/20 TSMP included Stress Free Temperature testing at several sites, and 13 sites were identified as special locations for the monitoring of track stability, including the Creighton derailment site.

ATSB has made a safety recommendation for ARTC to review its systems for the identification and management of track vulnerable to instability, considering the findings of this report.

Safety message

It is important for rail infrastructure managers to have systems in place to identify track sections vulnerable to lateral instability during the summer period.

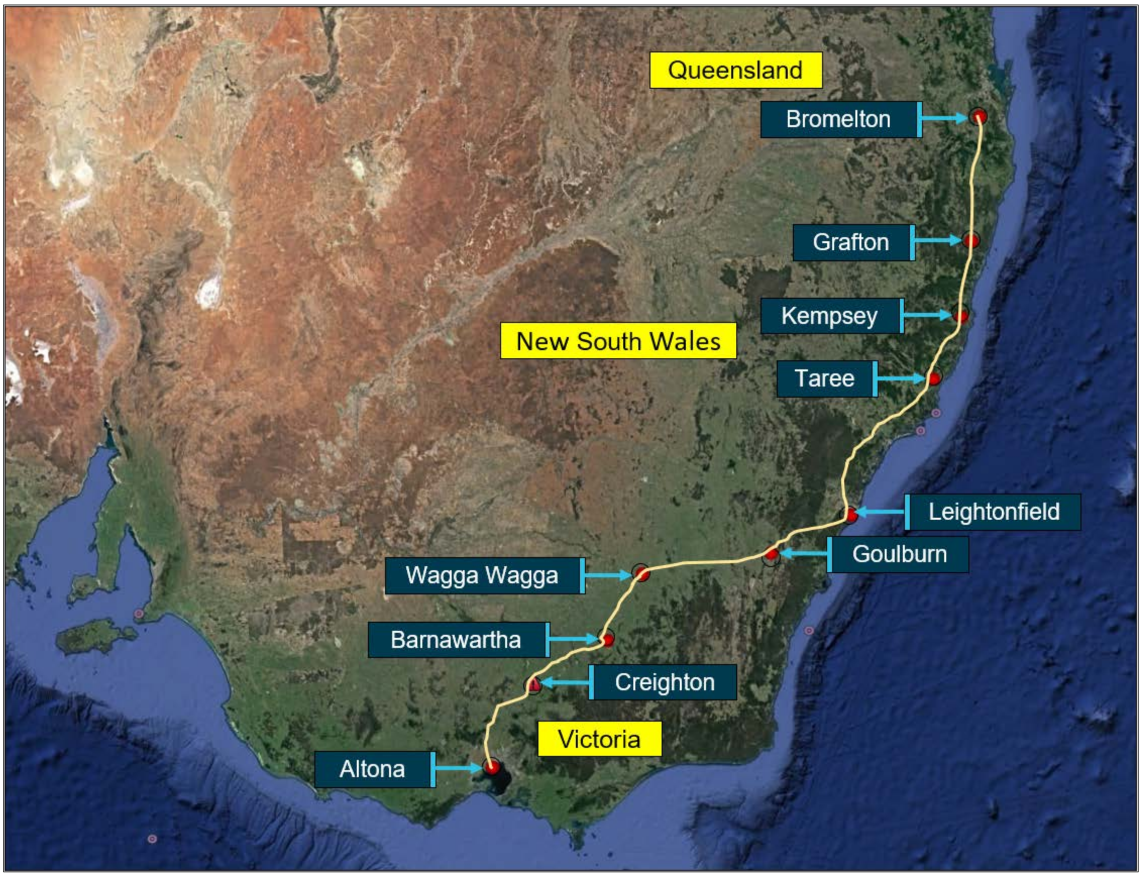
Contents

The occurrence

Events prior to the derailment

On the afternoon of 18 January 2019, SCT Logistics container service 6BM9 departed Bromelton in Queensland to travel to Altona in suburban Melbourne, Victoria (Figure 1). The train consisted of two locomotives hauling 18 wagons.

Figure 1: Intended route of train 6BM9 from Bromelton, Queensland to Altona, Victoria



Source: Google earth annotated by Chief Investigator, Transport Safety (Victoria)

The train arrived at Taree, New South Wales (NSW) at 0324 on Saturday 19 January, where there was a change of crew. The train then travelled to Leightonfield, for another crew change at about 1210 the same day. The next crew change was at Wagga Wagga at 1950, also on the same day. The next stage of the journey, between Wagga Wagga in NSW and Barnawartha in Victoria, was also uneventful, the train arriving just after midnight on 20 January.

Due to capacity constraints at its final destination in Melbourne, the train was held at the SCT Logistics terminal in Barnawartha for about 38 hours. During this stop, 13 wagons were added to the consist to give a total of 31. The train crew for the next leg joined the train on 21 January at about 1230. The train was inspected, and departed Barnawartha at about 1400.

The derailment

The train travelled in a south-west direction through Wangaratta, Benalla and Euroa. It was handling as expected out of Euroa, and crested Creighton Bank at a speed of about 95 km/h. On the downgrade following the crest, the train's speed increased to about 108 km/h.[1] The driver progressively reduced the throttle setting from Notch 8 to Notch 2 before crossing Creighton Siding Road at a speed of about 102 km/h. The train then crossed two short bridges before a wagon derailed immediately ahead of a third bridge at about 1540. The crew reported that they had not noticed any track irregularities prior to the derailment.

The driver stated that he saw a plume of dust towards the rear of the train in the rear view mirror and he also observed a loss of brake pipe (BP) pressure. The End-of-Train device (EOT)[2] registered a reduction in BP pressure, followed by a reduction of pressure in the locomotive electronic air brake (EAB)[3] system.

The train came to a stop with the lead locomotive just past the 141 km post. After stopping, the crew initiated an emergency call to network control. One of the crew then inspected the train and identified that the leading bogie of the third-last wagon (CTQY 666T) had derailed (Figure 2).

Figure 2: Derailed bogie of wagon CQTY 666T

Source: Australian Rail Track Corporation (ARTC).

[1] Train speeds provided are as recorded on the data logger from locomotive SCT004

[2] End-of-Train device measures brake pipe pressure on the last wagon and displays it on the driver's console.

[3] Electronic Air Brake (cab controls)

Observations following derailment

Immediately following the derailment and prior to the drop in temperatures that evening, the track at the derailment location was inspected by the rail infrastructure manager, the Australian Rail Track Corporation (ARTC). The track exhibited a significant lateral misalignment (Figure 3).

Figure 3: Track misalignment photographed at 1710 on 21 January, after derailment.

Source: Australian Rail Track Corporation

This photograph was taken soon after the derailment in temperatures similar to those existing at the time of the derailment, and prior to the track cooling overnight. It shows a significant track misalignment ahead of the rail bridge.

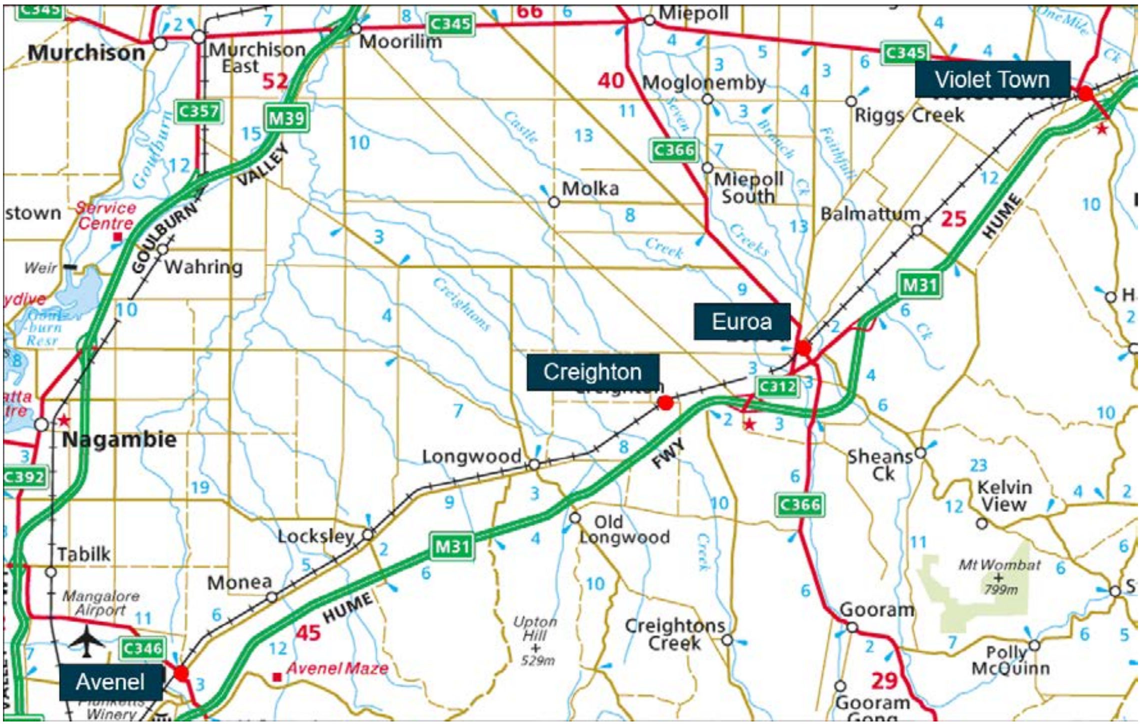
Context

Track information

Track location

Creighton is located in the rural municipality of the Strathbogie Shire Council in north central Victoria, about 143 rail-km from Melbourne (Figure 4).

Figure 4: Track between Violet Town and Avenel, indicating incident location Creighton



Source: e-way street directory, Melway 2017, annotated by Chief Investigator, Transport Safety (Victoria)

This rail corridor extends between Melbourne and Wodonga in northern Victoria and is part of the interstate standard-gauge[4] rail connection between Melbourne and Sydney. Since July 1998, the standard-gauge network in Victoria has been managed by the Australian Rail Track Corporation (ARTC).[5]

The corridor continues to receive significant investment. The North East Line Upgrade[6] project commenced planning in 2018, started works in 2019 and is due for completion in 2021. The scope of the project includes the removal of mud holes, drainage improvements, replacement of ballast and resurfacing including packing and compacting of ballast.

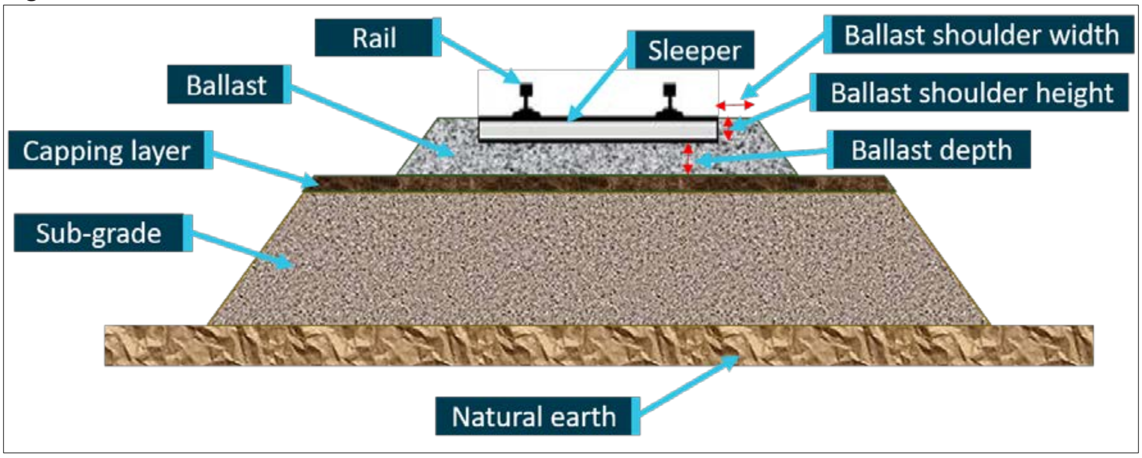
The standard-gauge track on the north east corridor has a history of mud hole formation and rough ride. In 2011, the ATSB conducted an investigation to examine the safety of rail operations on the Melbourne to Sydney line.[7] ATSB found that train forces on a weakened formation, as well as the effects of highly fouled ballast, poor drainage and heavy rainfall during 2010 and 2011, contributed to the development of mud-holes and poor vertical alignment on this corridor.

4 1435 mm gauge.
5 ARTC is incorporated under the Corporations Act, with all shares owned by the Commonwealth of Australia,
6 Managed by ARTC.
7 RO-2011-015 – Safety of rail operations on the interstate rail line between Melbourne and Sydney

Typical track construction

The structure of a track consists of a number of components, including the rail, sleepers, ballast and the formation (Figure 5).

Figure 5: Track structure



Source: Chief Investigator, Transport Safety (Victoria)

The formation is the earthworks upon which the ballast is laid and typically consists of the sub-grade (earth fill on top of the natural earth) and a capping layer of compacted material that provides a sealing layer to the sub-grade. The ballast covers the capping and distributes the loads to the formation while also providing the necessary support to the sleepers to maintain track geometry under vertical, lateral and longitudinal loads. Sleepers and their fastenings support and locate the rail.

Track at Creighton

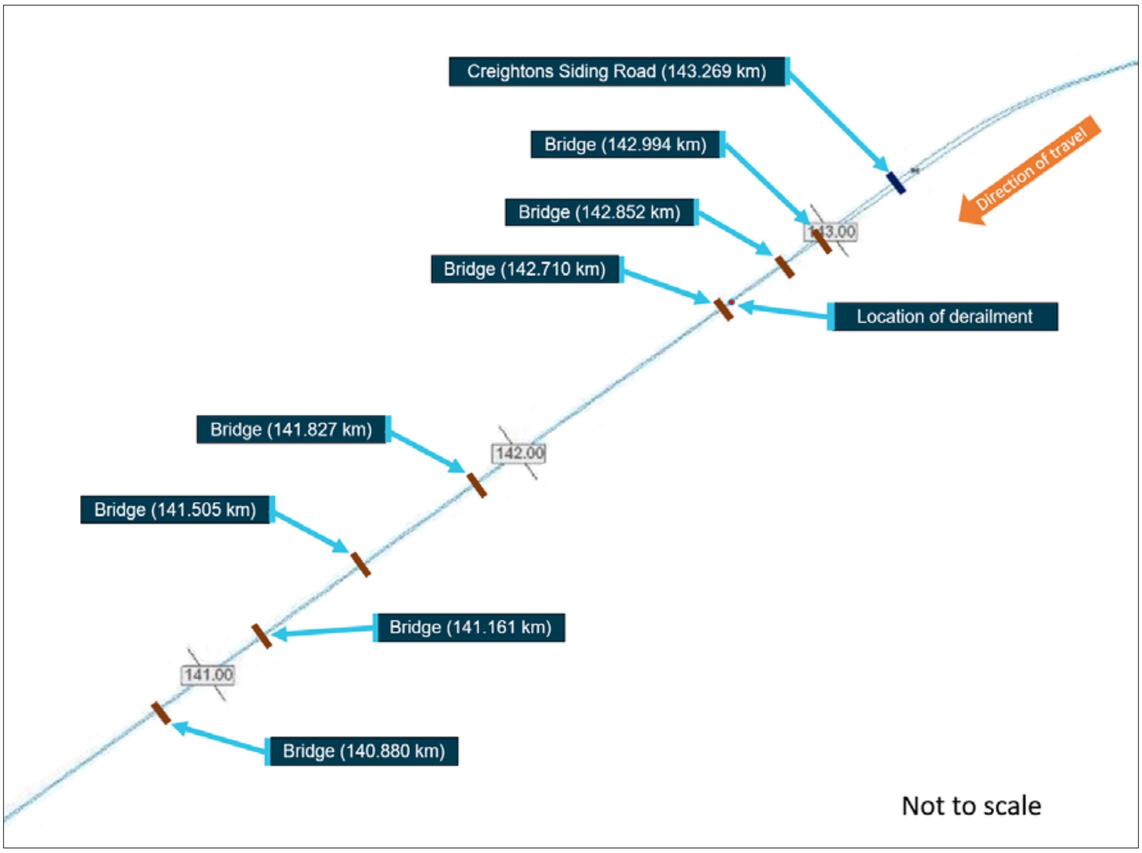
There were two parallel, standard-gauge bi-directional tracks at Creighton—an east and west track. The incident train was travelling towards Melbourne on the east track. The maximum permitted speed for this line segment was 130 km/h and there were no temporary speed restrictions in force at this location, nor had any speed restrictions been imposed due to heat. The authorised speed for the class of train that derailed was 115 km/h.[8]

The east track through Creighton was constructed using 60 kg/m Continuous Welded Rail (CWR)[9] affixed to 250 mm deep concrete sleepers using Pandrol 'fastclip' resilient fasteners. Concrete sleepers were at a nominal spacing of 667 mm.[10] Construction standards specified ballast at a depth of 250 mm and a shoulder width of 300 mm.[11] The standard stated that the ballast shoulder height be determined by the sleeper design.

Creighton Siding Road is located 143.276 rail-km from Melbourne.[12] Travelling towards Melbourne, there were seven rail bridges over a relatively short distance. They were located at 142.944 km, 142.852 km, 142.710 km, 141.827 km, 141.505 km, 141.161 km and 140.880 km (Figure 6). The derailment occurred a short distance before the bridge at 142.710 km, and the train came to a stop just prior to the bridge at 140.880 km.

8 Individual trains may be limited in speed depending on their class, rolling stock classification and other criteria.
9 Rail lengths welded end-to-end into strings greater than 400 m.
10 Australian Rail Track Corporation, Engineering (Track & Civil), Code of Practice, Sleepers and fastenings, Section 2, Version 2.0.
11 Australian Rail Track Corporation, Engineering (Track & Civil), Code of Practice, Ballast, Section 4, Version 2.4.
12 All chainage figures used in this report are based on the asset records maintained by Public Transport of Victoria. There are small differences between these figures and those used by ARTC.

Figure 6: Incident track section



Source: Pass Assets, Public Transport Victoria, Annotated by Chief Investigator, Transport Safety (Victoria)

Rail bridge construction

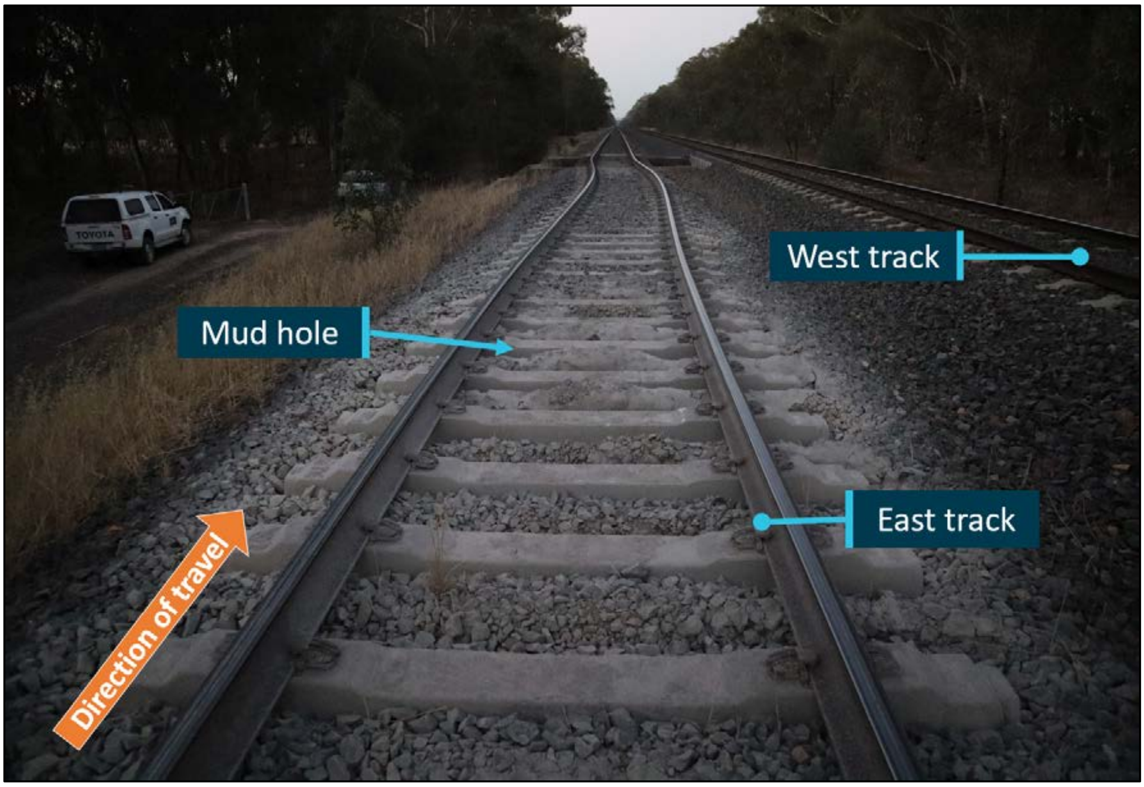
The point of derailment was between the short rail bridges at 142.852 km and at 142.710 km. Both bridges were transom bridges, with timber sleepers fixed to I-beam girders supported at each end by concrete abutments. Rails were secured to sleepers with Trak-Lok type fastenings that had a design toe load of approximately 9 kN for each fitting. The rail bridge at 142.710 km was about 7.4 m long and in good condition (Figure 7).

Post-incident track inspection

An examination of the track following the derailment identified misaligned track up to the 142.710 km rail bridge and associated lateral displacement of sleepers. Significant ballast fouling was observed from 16 to 27 m before the rail bridge. The most severe fouling and loss of ballast profile was from about 20 to 24 m prior to the rail bridge (Figure 7). A dip in the track through this mud hole location was observed.

Site evidence indicated that the initial derailment was of a single wheelset that had derailed to the left of the track before the bridge at 142.710 km. The point of mount of the left-hand wheel and the drop-off points of both wheels could not be determined with certainty. There was some indication of the right-hand wheel having dropped inside the right rail about 10 m before the rail bridge. There was further evidence indicating that the second wheelset (of the same bogie) derailed prior to the next bridge at 141.827 km.

Figure 7: Mud hole and track buckle on east track before bridge located at 142.710 km.

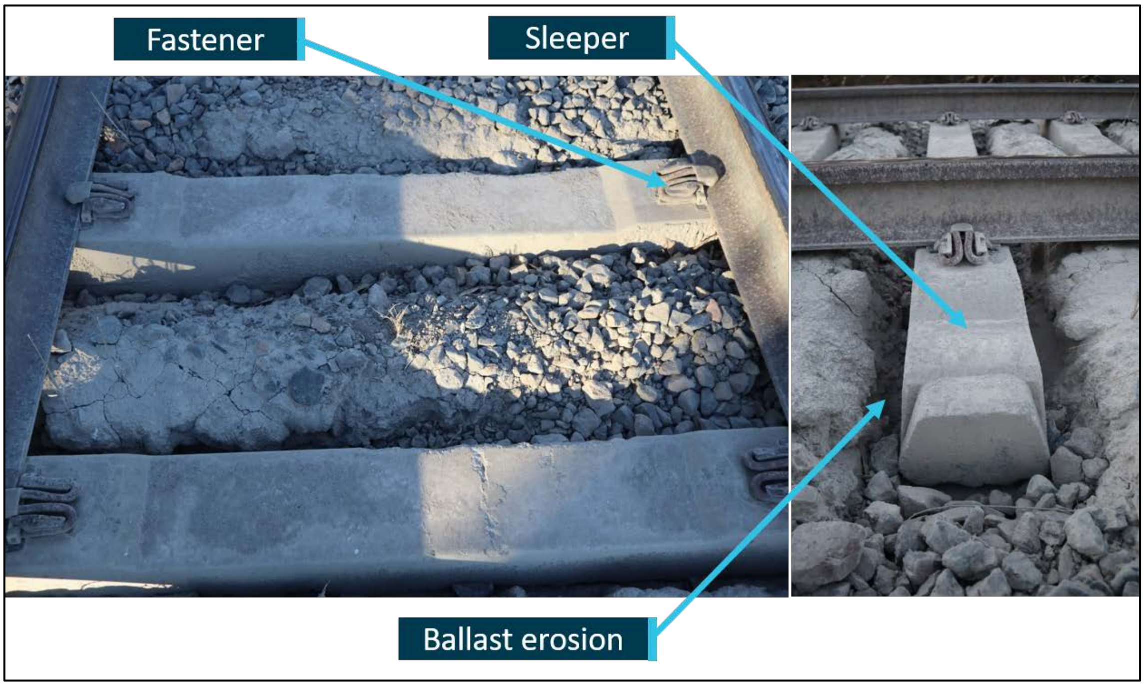


Source: Chief Investigator, Transport Safety (Victoria)

This photograph was taken in the early morning of the day following the derailment. The rails had contracted in the cooler overnight temperatures and the magnitude of the track misalignment had reduced from its peak. The photograph shows the heavy fouling of the ballast about 20-24 m ahead of a short rail bridge.

At the location of the mud hole there was severe contamination of the ballast and a loss of ballast between sleepers, and at sleeper ends (Figure 8).

Figure 8: Mud hole at the derailment location



Source: Chief Investigator, Transport Safety (Victoria)

Post-derailment rail stress free temperature measurements

Following the derailment, ARTC reinstated the track during cooler temperatures, and without the need to cut rail. Following track restoration, the stress free temperature (SFT) of each rail was measured by ARTC.[13] Measurements were made at 142.760 km on the evening of 23 January 2019, with rail temperatures at about 23°C. The ARTC measurements estimated an SFT in the Up rail (left rail looking towards Melbourne) of 34°C, and an SFT in the Down rail of 36°C. It is not known the extent to which stress in each rail may have been equalised along their length as a result of the derailment and the subsequent restoration works.

Pre-derailment track inspections

Track patrols and inspections

The ARTC Track and Civil Code of Practice detailed the requirements for track patrols, general inspections and detailed inspections.[14]

ARTC undertook track patrols every 7 days or as specified in their Track Maintenance Plan (TMP). These patrols were typically performed from road-rail vehicles. Unscheduled inspections were also carried out in response to 'defined or abnormal events' and included those required at special locations where defects were more likely.[15]

ARTC conducted a range of other general and detailed track inspections to monitor the condition of track infrastructure, ranging in frequency from 6 to 24 months. ARTC standards specified that the general inspection of track stability be conducted as temperatures started to increase after the cold season, normally the end of August, and as close as possible to, or in conjunction with, the ballast general inspection.

Inspection outcomes

Previous inspections had identified the presence of the mud hole on the Creighton (Down) side of the 142.710 km rail bridge, and this was recorded within the ARTC's *Routine Maintenance – Defect Work Orders*. Defect Work Orders for at least the previous two years indicated that the mud hole was monitored fortnightly but no remediation was undertaken.[16] The same inspection finding and response was made in all prior inspections with the report closed-out on the maintenance management system with the note 'remove mud hole, PO[17], supervisor, excavator, tamp, undercutter bar 36 tonne ballast'. The most recent track patrol inspection at the location prior to the derailment was conducted by road-rail vehicle on 14 January 2019.

There were no other specific findings or outstanding actions identified from previous general or detailed inspections at this location.

Track geometry

Track geometry was measured every four months using the 'AK-Car'[18] to assess geometry against maintenance standards. Parameters measured included track gauge, cant, twist and rail vertical and lateral variation.

---

13 Using VERSE system

14 ARTC, Track Patrol, Front of Train, General and Detailed Inspections ETE-00-02

15 Ibid.

16 The mud hole location is identified at ARTC chainage 142.688 – 142.700, that varies slightly from asset system chainages. This mud hole is the same mud hole as that identified on site immediately prior to the point of derailment.

17 Protection Officer.

18 The AK car is a track inspection vehicle also known as a track recording car used to test several geometric parameters of the track without obstructing normal railroad operations. The cars use a variety of sensors, measuring systems, and data management systems to create a profile of the track being inspected.

The most recent geometry measurements at the derailment location were made on 10 October 2018. The TOP[19] recorded by the AK car in the vicinity of the mud hole just before the bridge at 142.710 km indicated rapid changes in TOP measurement but was within permitted tolerance. As there was no exceedance of standards, no outstanding actions were recorded. The deviation in LINE[20] recorded by the AK car was no more than 5 mm in the vicinity of the mud hole, and was within permitted tolerance.

Management of lateral stability of track

Introduction

A track buckle occurs when the longitudinal expansion of rails in hot conditions leads to high compressive forces, and the track structure is unable to prevent the track from moving laterally to relieve the stresses developed within the rails. Managing the lateral stability of track therefore involves both the management of rail stress, and the design and maintenance of track support structures including ballast.

Management of rail stress

Continuously Welded Rail (CWR)

The ARTC code of practice for Track Lateral Stability specified a rail stress-free temperature (SFT) of 38°C in track with CWR. The SFT is the temperature at which there are no temperature induced stresses in the rail.[21] An SFT is chosen to minimise the potential for track buckle (in hot conditions) and for a rail break (in cold conditions). The SFT of a rail can change over time if there is longitudinal creep of the rail. CWR affixed to concrete sleepers using resilient fasteners has an enhanced ability to resist longitudinal creep forces.[22]

Rail fastenings

Rail fasteners generate a toe load on the rail flange, providing resistance to longitudinal movement, and to rail roll and lateral shift. High toe loads mean that rail and sleeper are more likely to act as a single assembly.[23] The resilient fastenings used on track at this location were Pandrol ‘fastclip’.[24] For concrete-sleepered track, the ARTC standard required a minimum designed toe load per rail seat (two fastening clips per rail seat) of 15 kN for track with axle loads not exceeding 25 t. Although toe load is related to longitudinal creep resistance, there is no direct and consistent relationship.

Monitoring of rail stress free temperature

ARTC track standards specified that rail creep monitoring and control measures would not usually be necessary at locations with CWR with concrete sleepers and resilient fastenings.[25] The standard noted that this arrangement was known to provide good resistance to longitudinal rail movements, but that ‘practices for the measurement of rail creep should be considered and take into account the influence of fixed points in the track’. [26] There were no creep monitoring facilities through the Creighton location.

---

[19] TOP is the up or down variation (vertical) from the mean alignment of the rail and is measured by the AK car.

[20] LINE is the variation on a horizontal plane from the mean alignment of the rail and is measured by the AK car.

[21] At the SFT, if a small section of rail was removed, the gap would remain constant. It would neither close nor widen unless the rail temperature was to change.

[22] Australian Railway Infrastructure standard AS7639:2013 Track Structure & Support.

[23] Nafis Ahmad, Shah Sanjar & Mandal, Nirmal & Chattopadhyay, Gopinath & Powell, J. & Micenko, P. (2011). Improvement of rail creep data to measure the stress state of a tangent continuously welded rail (CWR) track

[24] Australian Rail Track Corporation, Engineering (Track & Civil), Code of Practice, Resilient Rail fastenings for medium Duty Concrete Sleepers – Design ETD-02-02.

[25] Fastenings that exert a toe load on the rail foot inhibiting creep.

[26] Australian Rail Track Corporation, Engineering (Track & Civil), Code of Practice, Track Lateral Stability, Section 6, Version 2.5.

Changes in a rail SFT are not easily observed in CWR.[27] ARTC did not check SFT in CWR affixed to concrete sleepers unless it was identified during detailed inspection that the SFT may have lowered. In such cases, ARTC measured rail SFT using VERSE testing.[28] This testing involved unfastening 30 m of rail and lifting the rail by hydraulic jack. By measuring the lifting force and height, and the rail temperature at the time of the measurement, it was possible to estimate the temperature of the rail at which it would be stress free (the SFT). The ARTC Track Stability Management Plan for the Sydney to Craigieburn corridor for the 2018-2019 high temperature season did not require the SFT of rail to be measured through the Creighton location.

Ballast requirements for lateral resistance

Ballast performs a critical function in maintaining track stability. The ARTC standard[29] for ballast specified the required ballast profile, and the required corrective action should the profile be diminished (Table 1). Pictorial definitions of the reduced ballast profile are provided at Appendix A.

Table 1: ARTC Ballast Profile Condition - Response Codes

Ballast profile		**Profile simplified for field application**		**Response code**
Shoulder Height (H)	Shoulder Width (W)	Shoulder Height (H)	Shoulder Width (W)	Freight/Passenger 115/- km/h
≥ 3/4	≥ 1/4 to 3/4	Full	Half	A6
≥ 3/4	≥ 0	Full	Nil	A5
≥ 1/4	≥ 3/4	Half	Full	A5
≥ 1/4	≥ 1/4 to 3/4	Half	Half	A5
≥ 1/4	≥ 0	Half	Nil	A4
≥ 0	≥ 0	Nil	Nil	A3
Response	**Description of action required**			
A6	An appropriate increase in the monitoring and follow up action as required.			
A5	Temporary speed restriction of 80/90 or repair prior to the passage of the next train.			
A4	Temporary speed restriction of 60/65 or repair prior to the passage of the next train.			
A3	Temporary speed restriction of 40/40 or repair prior to the passage of the next train.			

The data was for track with concrete sleepers and curvature >400 m radius, and freight line speed of 115 km/h.
Source: ARTC

The response code table notes[30] state that ‘in concrete sleepers the responses apply where height and width deficiencies occur over 10 m or greater.

[27] By comparison, in jointed track the expansion and contraction of rail can be observed and simple measurements taken at joints to estimate the stress condition of the rail at temperature extremes.

[28] VERSE is a proprietary device used for non-destructively measuring the Stress Free Temperature in rail, and is marketed by Pandrol Australia Pty Ltd.

[29] ARTC Engineering (Track & Civil) Code of Practice, Section 4 Ballast, 5 September 2012

[30] Australian Rail Track Corporation, Engineering (Track & Civil), Code of Practice, Ballast, Section 4 - Note 2 to tables 4.3, 4.4 and 4.5.

Standard for special locations

ARTC procedures for managing track stability stated that a location that has an increased risk of track stability were defined as a special location.[31] Further, special locations are defined as areas:[32]

- potentially vulnerable to instability
- with a history of instability, or
- where the SFT is 'suspect'.

These procedures stated that special locations may require rectification work or more detailed inspections prior to the high temperature season and typically, special locations may include:

- track sections with a history of lateral instability or pull-apart failures
- bunching points
- areas with non-conforming ballast profile
- sites with localised initiators (e.g. mud holes).

The procedures specified that sites required to be monitored as special locations shall be determined and are to be recorded in the Asset Management System (AMS) and a register attached to the Track Stability Management Plan (TSMP).

Track Stability Management Plan

The Track Stability Management Plan (TSMP) was designed to be regularly updated and included actions to be undertaken to manage track lateral stability in accordance with ARTC standards and procedures.

The TSMP covering the Creighton location applied to defined sections of concrete-sleepered track between approximately 30 and 200 rail-km from Melbourne. It was last updated (prior to the derailment) on 24 September 2018,[33] and was endorsed by the Corridor Manager Sydney to Craigieburn. The plan included results of Stress Free Temperature (SFT) measurements since the previous plan review, and a schedule of planned SFT measurements. There were no 'previous' or scheduled SFT measurements at the derailment location.

The plan noted that after establishment of concrete sleepers between 200.614 and 99.305 km in 2016, inspections had indicated that there had been little or no evidence of creep. Creep measurements were no longer taken and SFT measurements were taken in locations identified during track inspections.

The plan detailed 'Buckling Resistance Management' and the requirement to define locations with ballast deficiencies that required temporary speed restrictions when forecast temperatures reached or exceeded 38°C.[34] There were no such locations identified within the plan.

The plan included a special locations register, although there were no locations listed on the plan provided.

Track buckling predictor

In 2017, ARTC published a document[35] on the use of a predictor model to assist with the prediction of instability by estimating the rail temperature at which the track was likely to buckle.

---

31 Australian Rail Track Corporation, Managing Track Stability, ETM-06-08, Version 1.1.
32 Australian Rail Track Corporation, Managing Track Stability, ETM-06-08, Version 1.1, Section 3.8.
33 Seymour Track Stability Management Plan
34 In accordance with ARTC Code of Practice – Section 4
35 Track Buckling Predictor ETI-06-06, Version 1.0, 16 March 2017.

The ARTC buckling predictor was based on the Schramm[36] and Bartlett[37] models developed in the 1960s. The Schramm model is an empirical model based on field data whereas the Bartlett had a combined empirical and theoretical basis. The output of the predictor model was an estimate the temperature of the rail at which the track may buckle.

The train

Locomotive crew

The drivers for this sector were suitably qualified and had been assessed as medically fit.

Locomotives and wagons

SCT Logistics container service 6BM9 from Barnawartha consisted of two locomotives SCT004, SCT012 and 31 wagons. The first 25 wagons were carrying containerised goods. Wagons 26 to 29 each carried two empty containers, while wagon 30 carried one empty container. The last wagon was not carrying any containers. The train was about 991 metres long and had a trailing tonnage of 2072 t.

The derailed wagon CQTY666T (wagon 29) was a two-slot container flat wagon loaded with two empty containers, each weighing about 2.28 t (Figure 9).

Figure 9: Derailed wagon CQTY 666T

Source: Advisian, Worley Parsons Group.

The wagon was travelling with its B-end leading with the lead bogie CAYE 6300 derailing. The wagon was fitted with AAR 2E, three-piece ride control bogies of nominal capacity 23 tonne axle load. The bogies were fitted with Stucki type constant contact side bearers and conventional AAR 4:1 brake rigging.

---

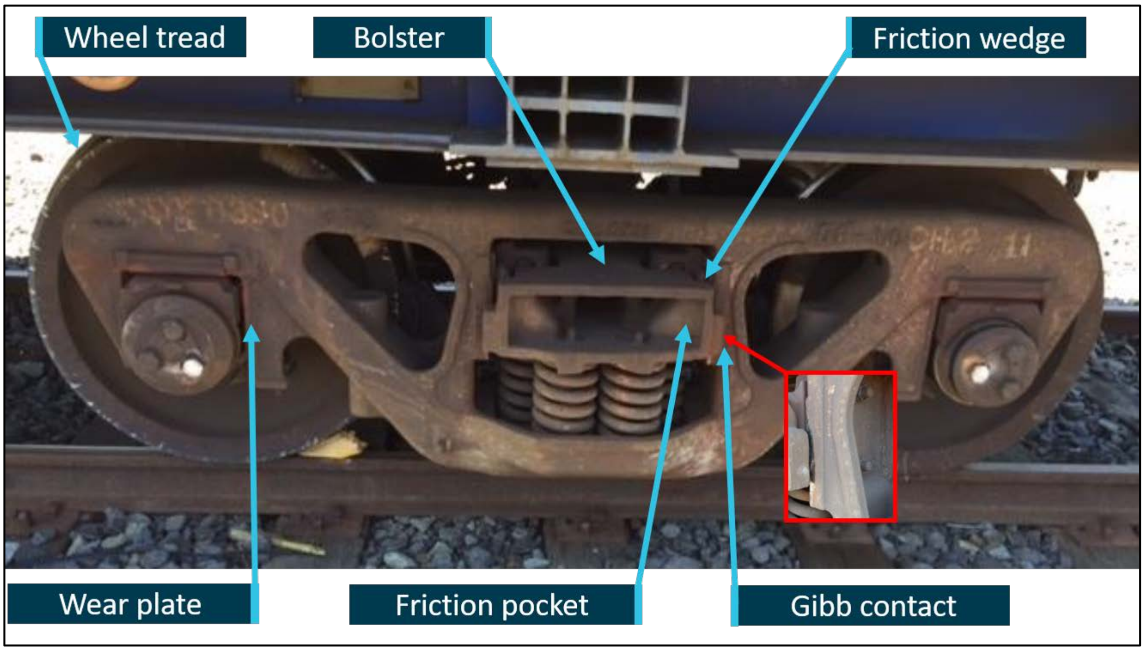
36 Schramm, G. (Trans. Lange, H.). Permanent Way Technique and Permanent Way Economy. 1st Edition. 1961.
37 Bartlett, D.L.(1960) The Stability of Long Welded Rails, Civil Eng. and Public Works Review Vol. 55, No. 649, 1033-1035, NO. 650, 1170-1171, No. 651, 1299-1303, No. 653, 1591-1593.

Post-incident inspection of wagon

Post-incident inspection of the wagon and the bogies revealed minimal wheel tread wear with moderate operational spalling damage. The light to moderate bolster gibb contact indicated either extended operation on poor track or bogie hunting.

Components of the friction wedge system such as wear plates, friction wedges and bolster pockets were all partially worn, while the wedges and side frame column wear plates were in good condition. The most likely cause of this wear would be inadequate attention to friction wedge pockets in the bolster at overhaul (Figure 10).

Figure 10: Bogie components



Source: Advisian, Worley Parsons Group, annotated by Chief Investigator, Transport Safety (Victoria).

Weather conditions

Around the time of the derailment, the temperature at Shepparton was approximately 38 °C. Shepparton is about 39 km from Creighton and it is probable that conditions at Creighton were similar. From 19 January, the Bureau of Meteorology had forecast a maximum temperature of 39 °C for Shepparton on 21 January 2019.

Safety analysis

Lateral Track Stability

When rail temperatures exceed the stress free temperature (SFT) of continuously welded rail (CWR), the rail will be in longitudinal compression. This scenario occurs regularly over the summer period. In this instance, the ambient air temperature was around 38°C. Rail, particularly when exposed to direct sunlight, reaches temperatures considerably higher than the ambient. In this instance, the rail temperature was probably of the order of 57°C.[38] This rail temperature is about 20°C above the nominal design SFT[39] and so rails would have been in a state of longitudinal compression in the environmental conditions at the time of the derailment.

Under such conditions, maintaining track stability relies on rail fastenings and track support, including ballast, to resist the forces acting to laterally misalign (buckle) the rails. Ahead of the rail bridge at 142.710 km, there was a mud hole and a loss of ballast profile around sleepers. This reduced resistance to track lateral movement and increased the potential for track instability at this location.

Site evidence was also consistent with a loss of track stability through this location. Deformed track formed an ‘S’ buckle that ended at the rail bridge. The bridge had probably acted as a fixed point.

Inspection of the derailed bogie did not identify defects or out-of-tolerance items, although there was some evidence of bogie hunting. The locomotive driver did not observe the misalignment ahead of the train, meaning the buckle developed under the dynamic loading of train 6BM9. It is possible that bogie behaviours influenced the magnitude of the load on the track. The wagon that derailed was carrying empty containers, probably making it more vulnerable to flange-climb derailment than the loaded wagons earlier in the consist.

Consequences

In this case, one bogie on the freight train derailed, resulting in minor track damage. However, had the bogie of train 6BM9 not derailed on the misalignment that had formed under the train, the XPT passenger service travelling from Sydney to Melbourne may have encountered the track misalignment. It was expected to pass through the location about 80 minutes after the derailment, at 1650.

Factors contributing to track instability

Methodology

In 2017 ARTC published a model for predicting the temperature at which track in a given condition may buckle. The prediction tool was based on older models developed by Bartlett and Schramm.

For this investigation, the part of the ARTC prediction tool that draws on the Bartlett model has been used to examine the potential for track buckle at the Creighton derailment location. Bartlett attempted to quantify the relative importance of rail, fastenings and ballast and developed a quasi-theoretical model.[40] It is recognised that the model provides an indication only of buckling temperature and sensitivity to key parameters, rather than definitive prediction. The sensitivity to buckling of three parameters are considered; ballast profile, the amplitude of a lateral defect acting as a buckle initiator, and the stress free temperature of the rails.

---

38 Rail temperatures may be fifty per cent more than ambient. Wu Y., Munro P., Rasul M.G., Khan M.M.K., A review of Recent Developments in Rail Temperature Prediction for use in Buckling Studies, RTSA Conference on Railway Engineering, Wellington, 2010. In this instance the rail was exposed to direct solar radiation.

39 The nominal SFT of rail on this corridor was 38 ± 5 °C.

40 ARTC document ETI0606T-01 Track Buckling Predictor, version 1.0, 16 March 2017, Technical notes.

For modelling using the ARTC buckling predictor, a number of parameters were fixed based on the conditions at site, and with some assumptions (Table 2).

Table 2: Input parameters used in predictor model

Parameter	Value	Fixed or variable
Rail weight (kg/m)	60 kg/m	Fixed for all scenarios
Sleeper spacing (mm)	660 mm[41]	Fixed for all scenarios
Type of sleeper and fastening	Concrete/Elastic	Fixed for all scenarios
Ballast shoulder width	Range 0-300 mm	Variable
Length – initial misalignment	10 m[42]	Fixed for all scenarios
Amplitude – initial misalignment	No set range	Variable
Rail stress free temperature	No set range	Variable
Wagon behaviour	Moderately hunting wagon[43]	Fixed for all scenarios
Tonnes of traffic since resurfacing	100,000[44]	Fixed for all scenarios

Sensitivity to reduced ballast profile

The potential influence of a loss of ballast profile on the predicted track buckling temperature was examined for a range of ballast shoulder widths,[45] and model predictions made for different values of initial misalignment, and rail stress free temperature (Table 3).

Table 3: Variables used in modelling sensitivity to ballast profile

Parameter	Value	Type of variable
Ballast should width	Range 0-300 mm	Primary variable
Amplitude – initial misalignment	10, 20 mm	Secondary variable
Rail stress free temperature	25, 30, 35°C	Secondary variable

The predicted buckling temperatures for a range of scenarios was compared to the estimated rail temperature at the time of the incident. The results of the prediction model indicate that at ballast shoulder widths of under 100 mm, track misalignment was plausible, particularly in the presence of a higher initial misalignment and/or lower rail stress-free-temperatures (Figure 11).

41 This value is set by the predictor model.

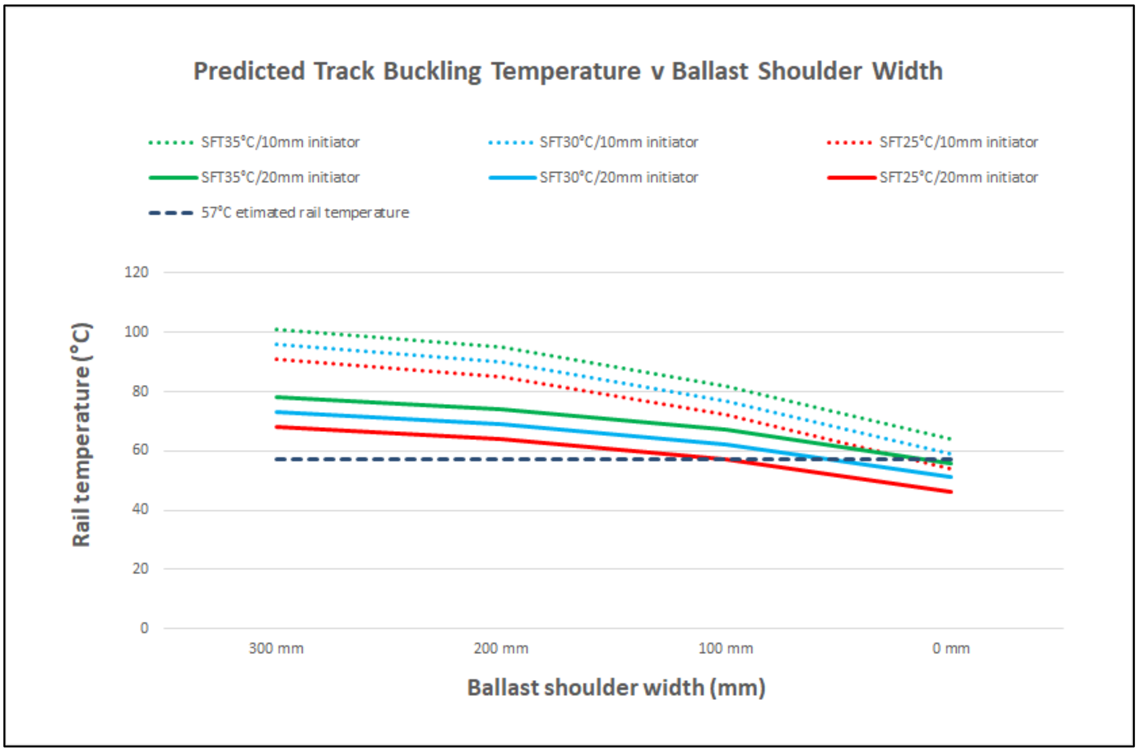
42 A nominal figure has been used consistent with the Schramm model set value of 10m.

43 The model specified options for a factor of 0.1 (Smooth riding wagon), 0.2 (Slightly hunting wagon), 0.3 (Moderately hunting wagon) or 0.4 (Badly hunting wagon). The factor 0.3 was used for all modelling based on the wagon inspection that suggested some hunting behaviour.

44 The model provides a range of 0 and 250000 for tonnes of traffic since resurfacing. This is a measure of interlocking and support of the ballast, and accounts for recent disturbance. Given the fouling and degradation of ballast in the vicinity of mud holes, a nominal, intermediate tonnage value of 100,000 has been has been used to minimise the impact of use of extreme values for this parameter.

45 The width of ballast shoulders at the end of sleepers.

Figure 11: The influence of ballast shoulder on predicted track buckling temperature



Source: Model information and tools published by ARTC, with input data by Chief Investigator, Transport Safety (Vic)

Local misalignment acting as buckle initiator

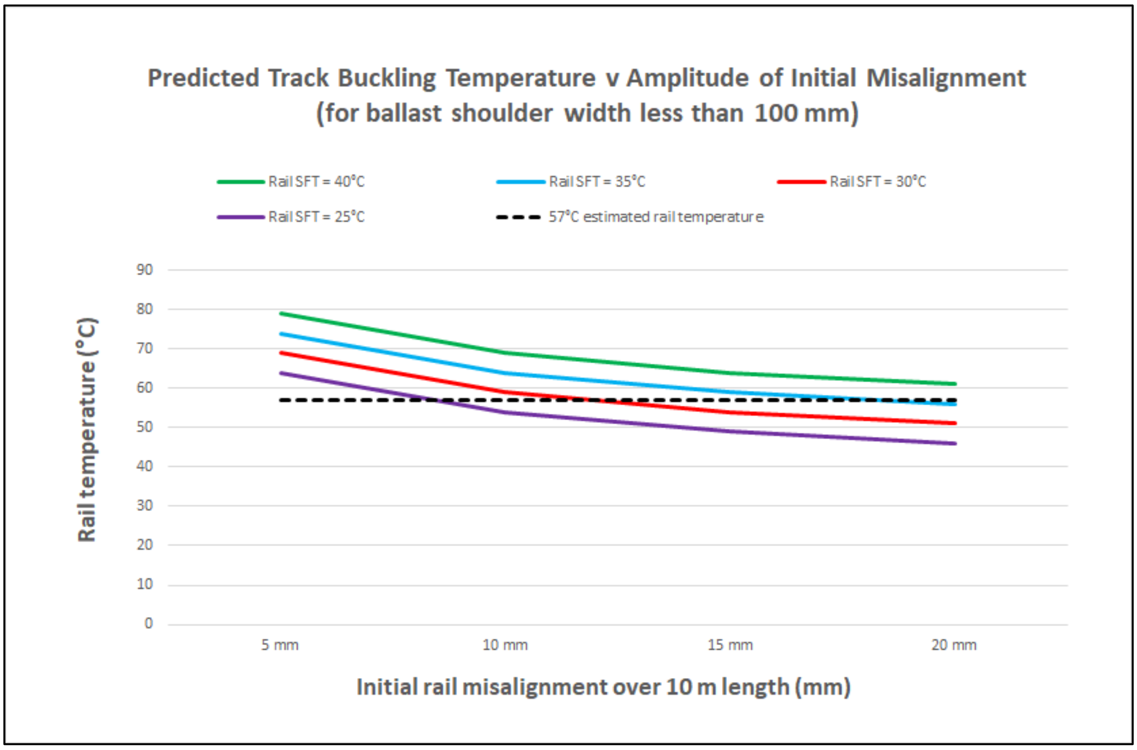
Ballast through the mud hole was significantly degraded. The potential impact of such a loss of support was two-fold. It resulted in a loss of lateral resistance to track buckle, and also the potential for the development of a lateral 'initiator' for track buckling. The most recent track geometry measurement was taken in October 2018, and indicated no lateral defects over 5 mm. However, the measurement was taken prior to the summer period before the derailment. The development within the mud hole of a buckle initiator of increased amplitude either over time, during the passage of other trains prior to train 6BM9, or under train 6BM9, are all possible scenarios. The sensitivity to the magnitude of an initial misalignment was modelled for a range of rail stress free temperatures and a fixed ballast shoulder width of less than 100 mm (Table 4).

Table 4: Variables used in modelling sensitivity to ballast profile

Parameter	Value	Type of variable
Amplitude – initial misalignment	5-20 mm	Primary variable
Rail stress free temperature	25, 30, 35, 40°C	Secondary variable
Ballast shoulder width	Less than 100 mm	Fixed value

The predicted buckling temperatures for a range of scenarios was compared to the estimated rail temperature at the time of the incident. The results of the predictor model indicate that the magnitude of the buckling initiator is a significant factor in the predicted magnitude of the lateral buckling force and the potential for a heat-induced buckle. The model suggests that with an initial lateral misalignment of over 10 mm, track buckle was plausible, particularly in the presence of lower rail stress-free-temperatures (Figure 12).

Figure 12: The influence of rail misalignment on predicted track buckling temperature



Source: Model information and tools published by ARTC, with input data by Chief Investigator, Transport Safety (Vic)

Variation of stress-free-temperature over a track section

The SFT of a rail can change over time, either by the rail moving through its fastenings or the track (rail with sleepers) creeping longitudinally. Research has found that SFT can vary considerably over a section of track, particularly near track features such as turnouts, crossings and bridges.

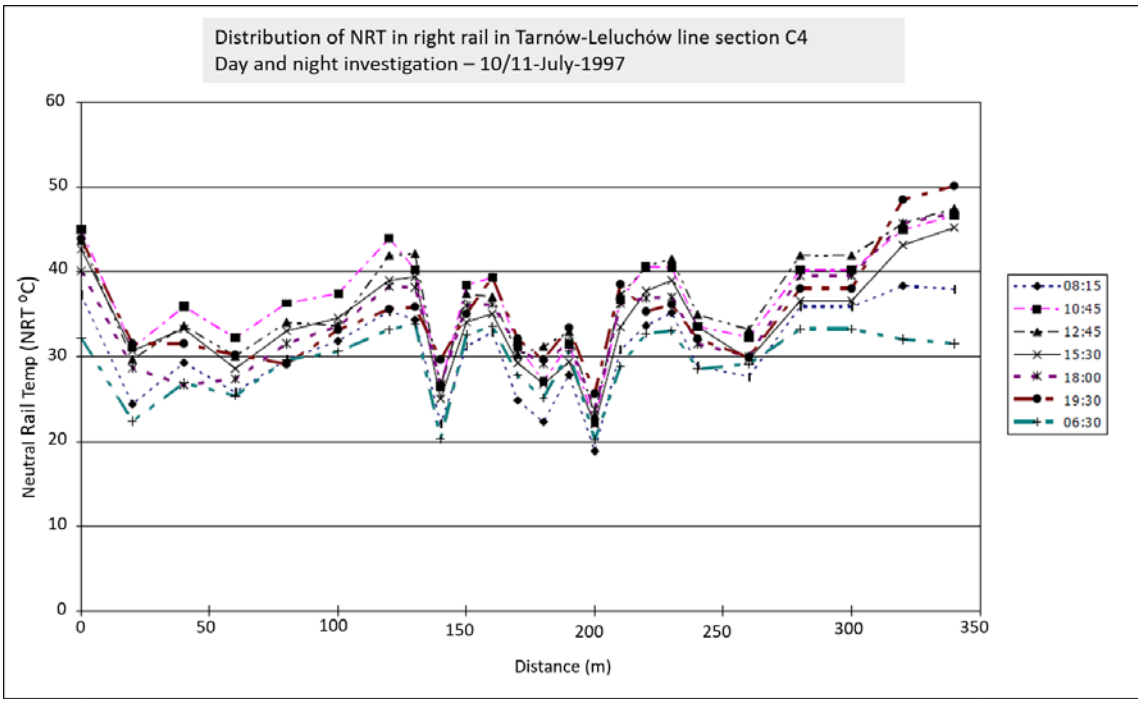
Esveld[46] reported on research commissioned by the International Union of Railways (UIC) to improve knowledge of forces in CWR track. This work included conducting simultaneous day and night measurements of longitudinal and lateral rail displacements, longitudinal forces in rails as well as temperature of rails in straight-line sections, sharp curves, turnouts and adjoining zones.

Figure 42 from this research (reproduced as Figure 13) shows the longitudinal distribution of stresses (shown as Neutral Rail Temperature (NRT) or SFT as used in this report) measured simultaneously across a 350 m section of tangent track through a complete day-night cycle. Esveld showed that for the rail section studied, the average SFT was approximately 33°C but the actual SFT varied along the length of rail due to two effects. Firstly a variation of about 7°C with a change in actual rail temperature as rail cools and heats during a 24 hour period and secondly, a variation from 27 to 40°C along the length of the rail during the hottest part of the day (in each case disregarding the readings at the extremities of the test section). Therefore, understanding the distribution of stress as well as the variation with ambient temperature is important to understand the risk of buckling.

---

46 Esveld C, Improved Knowledge of CWR Track retrieved 22 September 2020. [D202_Paris_98.PDF (esveld.com)]

Figure 13: Typical short-term track response on the straight section of CWR track when the lateral movements reach a few millimetres.



Source: C Esveld (1998) *Improved Knowledge of CWR Track*, ERRI Committee D202 paper on study commissioned by the International Union of Railways (UIC.

The ARTC standard for installing CWR on concrete sleepers specified an SFT of 38 ± 5 °C. Following this incident, the rails were unfastened, straightened and the SFT of each rail estimated using VERSE testing. The measurements were taken approximately midway between the bridges bounding the section of track in which the derailment occurred. There was not a large difference between the two rails, with their estimated SFT being 35 ± 1 °C.

This instance presented an unusual scenario with bridges at end of a section of about 140 m in length. The extent to which there may have been localised creep towards the bridge at 142.710 km prior to the derailment cannot be ascertained or estimated. By way of example, a localised additional compression of 2 mm over a 20 m length of rail equates to a reduction of about 8°C in the rail's SFT. This in turn would have the effect of heightening the likelihood of track instability.

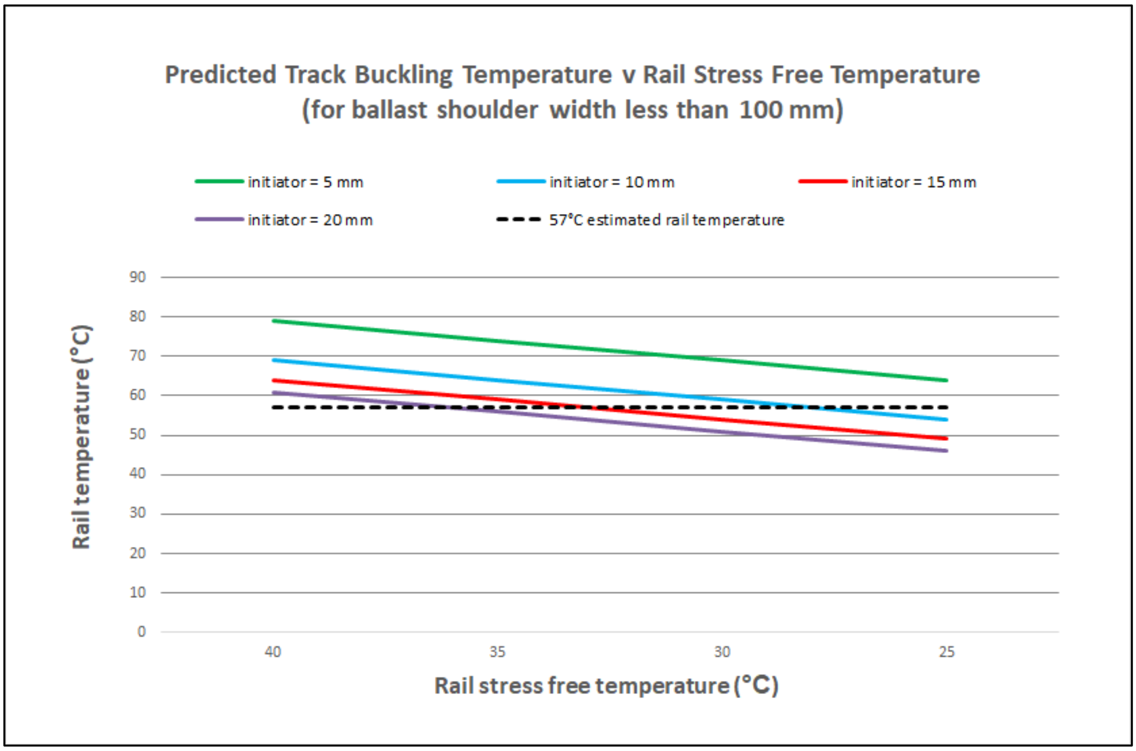
Using the ARTC predictor tool, the sensitivity to a localised reduction in rail SFT was predicted for a range of initial lateral misalignments (initiators) and a fixed ballast shoulder width of less than 100 mm (Table 5).

Table 5: Variables used in modelling sensitivity to rail stress free temperature

Parameter	Value	Type of variable
Rail stress free temperature	25, 30, 35, 40°C	Primary variable
Amplitude – initial misalignment	5-20 mm	Secondary variable
Ballast shoulder width	Less than 100 mm	Fixed value

A localised reduction of SFT of 5-10°C on the measured post-incident 35 °C ‘average’ for the section (to an SFT of 25-30°C) would have resulted in heightened likelihood of track buckle, particularly in the presence of an initial lateral misalignment of more than 10 mm (Figure 14).

Figure 14: The influence of rail SFT on predicted track buckling temperature



Source: Model information and tools published by ARTC, with input data by Chief Investigator, Transport Safety (Vic)

Summary

It is not feasible to determine the extent to which each facet of the track condition contributed to its instability and vulnerability to misalignment under loading from rail traffic. However, it can be concluded that a reduced ballast profile through the location contributed to track instability either through a broad loss of lateral resistance, or a localised loss of resistance that resulted in an increased value of initial misalignment (buckling initiator).

Any localised reduction in SFT in the rails abutting the rail bridge would also have increased the likelihood of a track buckle forming at this location.

Management of lateral stability at mud-holes

Standards for managing stability

Track ballast

To support management of track stability, ARTC specified maintenance requirements for track ballast, and associated response measures for reduced ballast shoulders. Maintenance records indicate that the mud hole was being monitored (response code A6) and the mud hole listed on the *Routine Maintenance – Defect Work Orders*. This response was probably in compliance with the ARTC code of practice that specified response codes for a shoulder deficiency over at least 10 m. While the localised ballast profile deficiency in the more severely contaminated area was probably consistent with the profile identified for an A5 or A4 response, this deficiency did not extend the 10 m required by the Code to trigger such a response.

Special locations and treatment

ARTC procedures for managing track stability categorised locations that had an increased risk of track instability as special locations. This potentially included sites with localised initiators like mud holes. The mud hole at Creighton had been identified by ARTC but had not been categorised as a special location. The procedures did not provide clear guidance to field staff on facets of ballast condition within a mud hole that might trigger its designation as a special location. Such criteria may have included mud hole severity, length or proximity to a fixed point that may heighten the track's vulnerability to lateral instability.

Special locations required rectification work or more detailed inspections prior to the high temperature season. As the Creighton location was not identified as a special location, it was not remedied in line with the special location process.

Track Stability Management Plan

The Track Stability Management Plan (TSMP) was designed to be regularly updated and included actions to be undertaken to manage track lateral stability in accordance with ARTC standards and procedures. The plan detailed 'Buckling Resistance Management' and the requirement to define locations with ballast deficiencies that required temporary speed restrictions when forecast temperatures reached or exceeded 38°C.[47] There were no such locations identified within the plan for the 170 km section that included Creighton.

The plan noted that after establishment of concrete sleepers in 2016, inspections had indicated that there had been little or no evidence of creep. Creep measurements were no longer taken by ARTC and therefore the evidence base for this commentary within the TSMP is unclear.

SFT measurements were taken at locations identified as those where SFT may have been compromised. Evidence suggests identified locations were mostly those areas that had been affected by track disturbance. The criteria for the selection of other sites for SFT testing, that had no clear trigger such as disturbance or compromised geometry, were not clearly defined.

[47] In accordance with ARTC Code of Practice – Section 4

Rail stress management

In those areas on this corridor with established concrete-sleepered CWR track, ARTC did not have a program of network-wide monitoring of rail stress. This maintenance policy appears based on the position that this type of track construction was less likely to creep, and lead to variation in rail SFT of a magnitude that would trigger track buckle or rail breaks. Monitoring of variation in SFT was limited to those sites identified by inspection or following track disturbance, typically from maintenance activity.

The regime established by ARTC for the management of rail stress may not identify all locations in the network with potentially problematic variation in SFT. It could not be established whether the suite of standards and procedures used by ARTC to manage rail SFT, and its implications on track stability, adequately managed this risk.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

Safety issues are highlighted in bold to emphasise their importance. A safety issue is a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to derailment of freight train 6BM9.

Contributing factors

- A mud hole and the associated loss of ballast resulted in a reduction in track lateral resistance at the derailment location.
- There were significant longitudinal compressive forces in the rails at the derailment location due to the hot conditions of the day and possibly localised reduction in rail SFT leading into a rail bridge.
- The combination of reduced track lateral resistance and longitudinal compression within the rails was sufficient for the track to misalign under the dynamic loading of train 6BM9, and for one wagon to derail.
- The loss of ballast profile at the derailment location probably required a more significant level of response than being monitored, such as a temporary speed restriction or repair.
- **The ARTC systems for managing track lateral stability did not lead to the location being managed as a location potentially vulnerable to instability. [Safety issue]**

Other findings

- ARTC systems for monitoring rail stress free temperature (SFT) in concrete-sleepered CWR track probably did not identify all locations that have SFT outside the Code of Practice guidelines.

Safety issues and actions

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues. The ATSB expects relevant organisations will address all safety issues an investigation identifies.

Depending on the level of risk of a safety issue, the extent of corrective action taken by the relevant organisation(s), or the desirability of directing a broad safety message to the rail industry, the ATSB may issue a formal safety recommendation or safety advisory notice as part of the final report.

All of the directly involved parties are invited to provide submissions to this draft report. As part of that process, each organisation is asked to communicate what safety actions, if any, they have carried out or are planning to carry out in relation to each safety issue relevant to their organisation.

Management of track lateral stability

Safety issue description

The ARTC systems for managing track lateral stability did not lead to the location being managed as a location potentially vulnerable to instability.

Issue number:	RO-2019-003-SI-01
Issue owner:	Australian rail Track Corporation
Transport function:	Rail: Freight
Current issue status:	Open - Safety action pending.

Response by Australian Rail Track Corporation

The ARTC advised that this location was not deemed to be a special location. The process for identifying special locations, targets locations susceptible to incorrect SFT and instability.

Safety recommendation to the Australian Rail Track Corporation

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	RO-2019-003-SR-015
Responsible organisation:	Australian Rail Track Corporation (ARTC)
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that the Australian Rail Track Corporation reviews its processes and criteria for identifying and managing track locations vulnerable to lateral instability, considering the findings of this investigation report.

Additional safety action by Australian Rail Track Corporation

ARTC advised that their Track Stability Management Plan (TSMP) for the 30-200 km section had been reviewed by its internal audit team. As part of the 2019/20 TSMP, 10 sites had been subject to VERSE (Stress Free Temperature) testing, and 13 sites identified as special locations for the monitoring of track stability. This included the Creighton derailment site.

General details

Occurrence details

Date and time:	21 January 2020 – 1540 EST	
Occurrence category:	Incident	
Primary occurrence type:	Derailment	
Location:	Creighton, Victoria	
	Latitude: 36º 47.258' S	Longitude: 145º 28.044' E

Train details

Track operator:	Australian Rail Track Corporation	
Train operator:	SCT Logistics	
Train number:	6BM9	
Type of operation:	Freight	
Consist:	Two locomotives and 31 freight wagons.	
Departure:	Bromelton, Queensland	
Destination:	Altona, Victoria	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 0	Passengers – 0
Damage:	Substantial train and track damage.	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Australian Rail Track Corporation
- SCT Logistics
- Locomotive drivers
- Recorded data from locomotive data loggers

References

Nafis Ahmad, Shah Sanjar & Mandal, Nirmal & Chattopadhyay, Gopinath & Powell, J. & Micenko, P. (2011). Improvement of rail creep data to measure the stress state of a tangent continuously welded rail (CWR) track.

Schramm, G. (Trans. Lange, H.). Permanent Way Technique and Permanent Way Economy. 1st Edition. 1961.

Bartlett, D.L.(1960) The Stability of Long Welded Rails, Civil Eng. and Public Works Review Vol. 55, No. 649, 1033-1035, NO. 650, 1170-1171, No. 651, 1299-1303, No. 653, 1591-1593.

Wu Y., Munro P., Rasul M.G., Khan M.M.K., A review of Recent Developments in Rail Temperature Prediction for use in Buckling Studies, RTSA Conference on Railway Engineering, Wellington, 2010. In this instance the rail was exposed to direct solar radiation.

Esveld C, Improved Knowledge of CWR Track www.esveld.com/Download/TUD/D202_Paris_98. PDF retrieved 22 September 2020.

Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

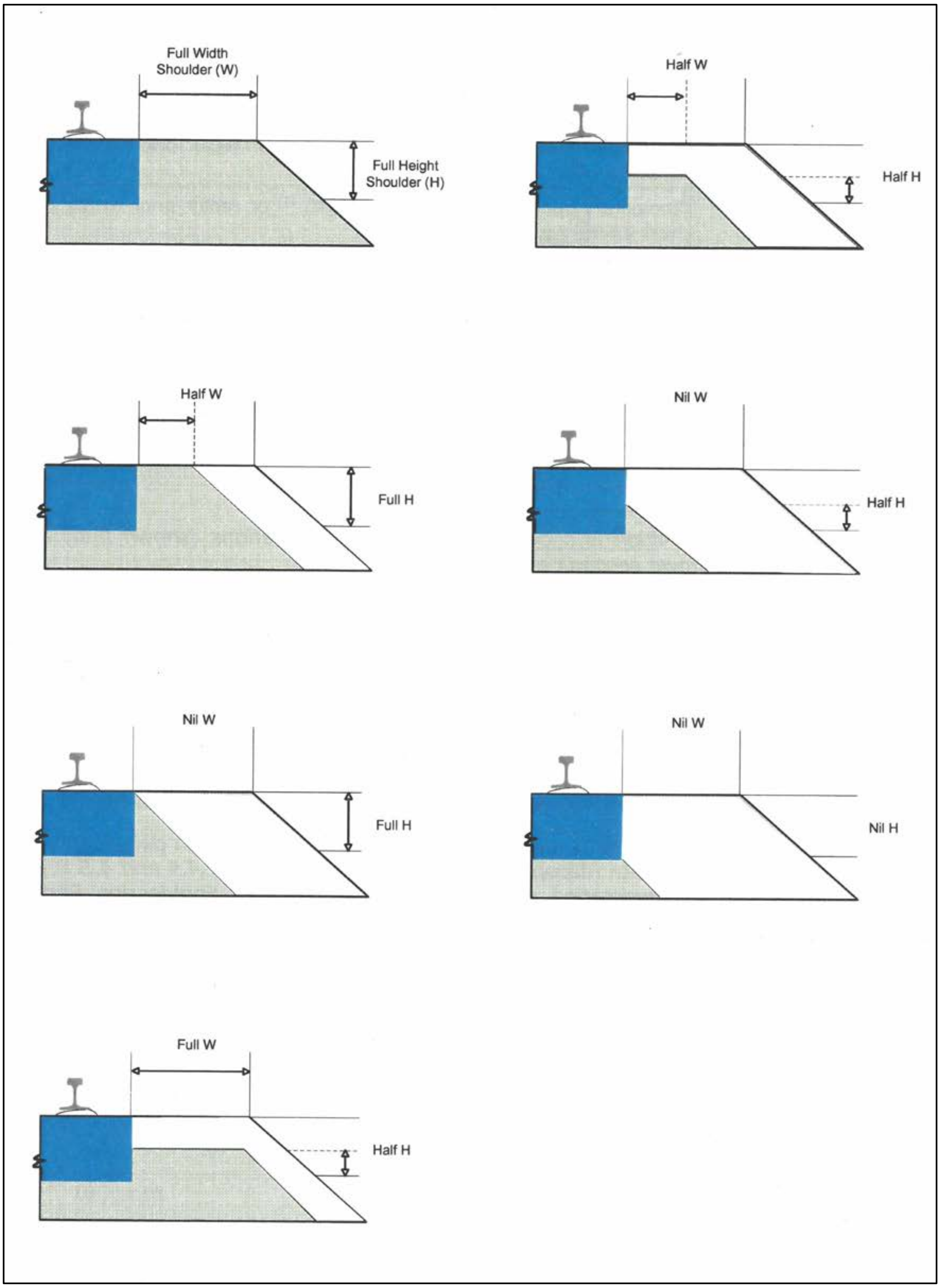
Submissions were received from:

- Australian Rail Track Corporation
- SCT Logistics
- Office of the National Rail Safety Regulator

The submissions were reviewed and, where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – ARTC pictorial definitions of reduced ballast profile



Source: ARTC Engineering (Track & Civil) Code of Practice Section 4 Ballast

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- independent investigation of transport accidents and other safety occurrences
- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, international agreements.

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.