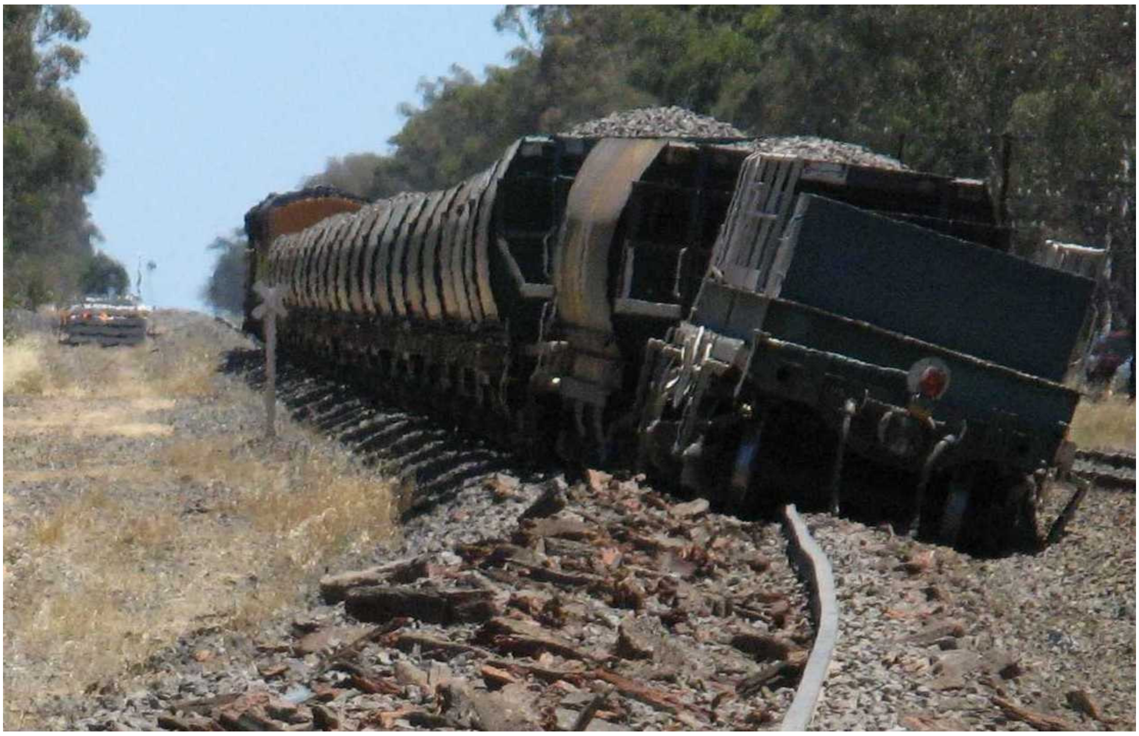
Office of the Chief Investigator
Transport and Marine Safety Investigations

Rail Safety Investigation
Report No 2008/12

Derailment
Ballast Train
Longwood
11 December 2008



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THE CHIEF INVESTIGATOR

The Chief Investigator, Transport and Marine Safety Investigations is a statutory position established on 1 August 2006 under Part V of the *Transport Act 1983*.

The objective of the position is to improve public transport and marine safety by independently investigating public transport and marine safety matters.

The primary focus of an investigation is to determine what factors caused the incident, rather than apportion blame for the incident, and to identify issues that may require review, monitoring or further consideration. In conducting investigations, the Chief Investigator will apply the principles of 'just culture' and use a methodology based on systemic investigation models.

The Chief Investigator is required to report the results of investigations to the Minister for Public Transport and/or the Minister for Roads and Ports. However, before submitting the results of an investigation to the Minister, the Chief Investigator must consult in accordance with section 85A of the *Transport Act 1983*.

The Chief Investigator is not subject to the direction or control of the Minister(s) in performing or exercising his or her functions or powers, but the Minister may direct the Chief Investigator to investigate a public transport safety matter or a marine safety matter.

EXECUTIVE SUMMARY

At about 0738 on 11 December 2008, the last two wagons of a ballast train running on the Defined Interstate Rail Network derailed shortly after passing across the Down Street level crossing in Longwood, north-east of Seymour. The derailed wagons were a ballast wagon and a ballast plough wagon. The derailment caused damage to the track and the derailed wagons. No persons were injured.

The investigation found that it is probable the derailment was the result of the leading right-hand wheel of the second last wagon, the last ballast wagon, climbing the right-hand rail about 25 metres after passing across the level crossing.

Modelling undertaken by the investigation indicated that the wheel-climb was due to the dynamic response of the ballast wagon to the track geometry through the level crossing and in the 25 metres following the crossing. The track ballast was fouled with mud and track irregularities were probably exaggerated by the dynamic action of the train.

In addition to the track geometry, other pre-conditions likely to have been factors in the derailment occurring at this point were the loaded state of the wagon, the configuration of the wagon suspension, the condition of the wheels and the train speed.

The Australian Rail Track Corporation advised that since the incident the site has been reinstated using concrete sleepers, the track lifted 100 mm, the level crossing renewed and more robust processes implemented for the reporting and assessment of mud holes.

The investigation makes recommendations in the areas of track standards and inspection, interaction between rolling stock and track, the loading of ballast wagons and operator safety management systems.

1. CIRCUMSTANCES

As part of the SIA (South Improvement Alliance)[1] project, SSRS (South Spur Rail Services Pty Ltd) was contracted to haul 24 wagons, comprising mostly ballast wagons, from Violet Town to Wallan. SSRS provided the locomotives and train crew for the operation and ARTC (Australian Rail Track Corporation) provided the wagons.

Running on the standard gauge north-east line of the DIRN (Defined Interstate Rail Network), train number 9644 departed Violet Town on 11 December 2008 at about 0700. The train stopped for a short time en-route for the crew to correct a locomotive equipment problem and then continued towards Wallan.

At around 0738, after crossing the Down Street level crossing in Longwood, the train lost brake pipe air pressure and came to a stop with the lead locomotive about a kilometre past the crossing. On inspection, the locomotive crew discovered that the last two wagons of the train had derailed to the right-hand-side of the track.

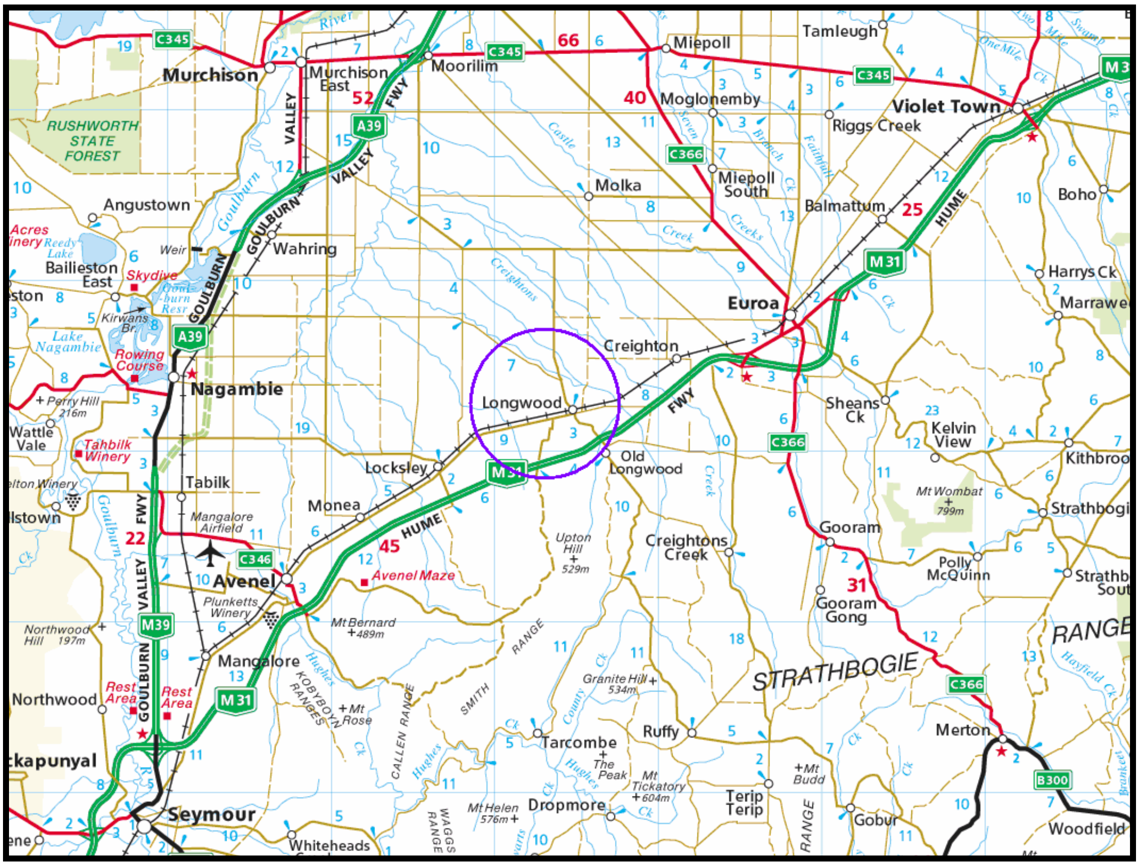

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Figure 1 – Location of Longwood

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[1] The SIA is the group of organisations brought together by the ARTC to plan, design and deliver a range of improvements along the Sydney – Melbourne rail corridor. The principal alliance partners were the ARTC, John Holland Rail, MVM Rail and O'Donnell Griffin.

The derailment of the wagons resulted in damage to a railway bridge and about 650 metres of track. There were no injuries to persons.

After the incident, a portion of the adjacent, non-operational, broad-gauge track was regauged to provide a standard-gauge route around the damaged track. The damaged line was subsequently reinstated using concrete sleepers.

2. FACTUAL INFORMATION

2.1 The train

2.1.1 The service

SSRS has advised that their contract to “hook-and-pull” the ballast train was with JMJV, a joint venture between SIA members John Holland Rail and MVM Rail. The investigation was unable to confirm the contractual arrangement between JMJV and ARTC, the owner of the wagons.

2.1.2 Train crew

The train was crewed by a locomotive driver and driver’s assistant who had both been assessed as medically fit for duty. At the time of the incident, the train was being driven by the locomotive driver.

Both crew members were suitably qualified to perform their respective train operation and train inspection duties on the day of the incident.

2.1.3 Locomotives and wagons

Train 9644 consisted of three locomotives hauling one NDPF ballast plough/equipment van, 22 NDFF ballast wagons and one NZBF ballast plough wagon. The train was about 342 metres long and had an approximate mass of 1685 tonnes.

The derailed wagons were the last two wagons of the consist; a ballast wagon and the ballast plough wagon. The derailed ballast wagon NDFF2223S had a tare of 19.8 tonnes, a capacity of 54 tonnes and a nominal length of 11.7 metres. The derailed plough wagon NZBF1045S had a tare of 33 tonnes and a nominal length of 11.6 metres.

Figure 2 – Derailed plough wagon NZBF1045S and ballast wagon NDFF2223S

2.1.4 Ballast wagon loading

In its standing agreement with SSRS, JMJV has responsibility for ensuring "… rolling stock is loaded and secured in accordance with all applicable loading and safety requirements, regulations and codes and that limits are not exceeded …". However, it is the understanding of the investigation that, in practice, ARTC and its contractors and other SIA partners may also be actively involved. Therefore, for ease of reporting and in recognition of the leading role of ARTC in the SIA project, the report refers to ARTC.

At the Violet Town siding, track ballast is supplied and loaded by Violet Town Quarries. Having earlier received an order for ballast from ARTC, the quarry manager typically receives a telephone call from the train driver when the wagons are at the siding and ready for loading. Rail personnel are not present during the loading operation. The ARTC had not provided the Quarry with documented guidance on the loading of its wagons and rail safety requirements.

Loading of train 9644 was undertaken on 10 December 2008 by the quarry manager who had over 20 years experience in this type of operation. The loading was by a front-end-loader which could load six to seven tonnes of ballast per bucket.

Figure 3 – Violet Town siding, showing ballast stockpile

The eye-level of the loader operator is just above the top of the wagon, allowing the operator to monitor the state of the ballast mound and correct a load which is identified as being significantly to one side in the hopper.

The front-end-loader is fitted with a weighing system which the operator uses to tally the total weight of ballast loaded to each wagon. When near capacity, the operator adjusts the amount of ballast in the bucket to get as close as possible to the desired 54 tonnes total ballast load, reportedly within a tolerance of around plus or minus 200 kilograms. There is no method of recording the total amount loaded into each wagon and the electronic weighing system is restarted for each wagon. There is also no documented method of calibrating the loader weighing system. Ad-hoc checks are made at the quarry site by comparing the loader's measured weights with weighbridge results for road transport deliveries.

Violet Town Quarries does not have a set or documented procedure for checking the condition of the load once all wagons are loaded. On occasion, the loader operator may climb onto a wagon and look along the rake to 'eyeball' the load and check for any asymmetrical loading or wagon lean.

2.1.5 Pre-departure train inspection

The SSRS Rail Safety Manual specifies train crew actions for the marshalling, preparation, inspection and brake testing of the train consist. Included in these pre-departure checks is the 'General Train Inspection FX2 (GX)'. The FX2 inspection includes a general visual mechanical inspection and, in relation to the loaded condition of the wagons, requires that the train crew:

"e. Visually inspect side bearers for lack of clearance or for excessive clearance.

f. Visually inspect main bogie for any broken loose or missing springs, inspect main bogie components for obvious defects or for any possible off centre occurrences.

k. Visually inspect load positioning and security … "

The scope of this pre-departure inspection does not include a detailed assessment of wagon load weight or evenness except as may be detected visually in more extreme cases.

For this service, a Train Inspection Certificate was completed by the train crew indicating that a 'General' inspection was undertaken between 0610 and 0645.

2.1.6 Rolling stock maintenance

The standing agreement with SSRS places obligations on JMJV to "… provide rolling stock that has been properly maintained …". However, ownership of the wagons was confirmed as residing with ARTC and maintenance records indicated that maintenance of the wagons was undertaken by ARTC and its contractors.

Prior to the incident, the most recent routine maintenance inspection of the derailed wagons was completed by the ARTC on 1 October 2008. In the two years prior, repairs and maintenance of the wagons had been undertaken by United Group Rail and the RIC (Rail Infrastructure Corporation[2]).

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[2] RIC (The Rail Infrastructure Corporation) is the owner of NSW non-metro rail networks. RIC was initially formed in 2001 having overall management responsibility for the NSW rail network. In January 2004, metropolitan system responsibilities were transferred to RailCorp. Then, in September 2004, RIC leased the NSW Interstate and Hunter Valley Networks to ARTC for 60 years and entered into a management agreement with ARTC to operate the Country Regional Network.

2.1.7 Rolling stock inspections following incident

The train was inspected at the incident site and the derailed wagons further inspected at a maintenance depot. Post-incident inspection of the two derailed wagons did not identify any deficiency or other condition attributable to poor maintenance.

The ballast wagons were observed to be fully laden and in some cases the load uneven. There was evidence of bogie spring coil binding[3] having occurred on the ballast wagons, indicating that the suspension of the bogies had been, at times, worked to their limits of compressibility. The ballast plough/equipment van and the ballast plough wagon were observed to have their ploughs raised clear, secured and padlocked.

Figure 4 – Typical ballast wagon bogie suspension spring showing evidence of spring coil binding

Ballast wagon NDFF2223S

The body and under-frame of the ballast wagon had suffered localised damage during the incident. The brake pipe beneath the hopper had suffered impact damage from the leading bogie resulting in the separation of a brake pipe fitting at the triple valve pipe bracket on the left-hand side of the leading end of the wagon. Other damage included a puncture of the hopper slope sheet caused by the frame of the leading bogie.

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[3] Spring coil binding occurs when there is contact between spring coils due to the spring being compressed to its limits.

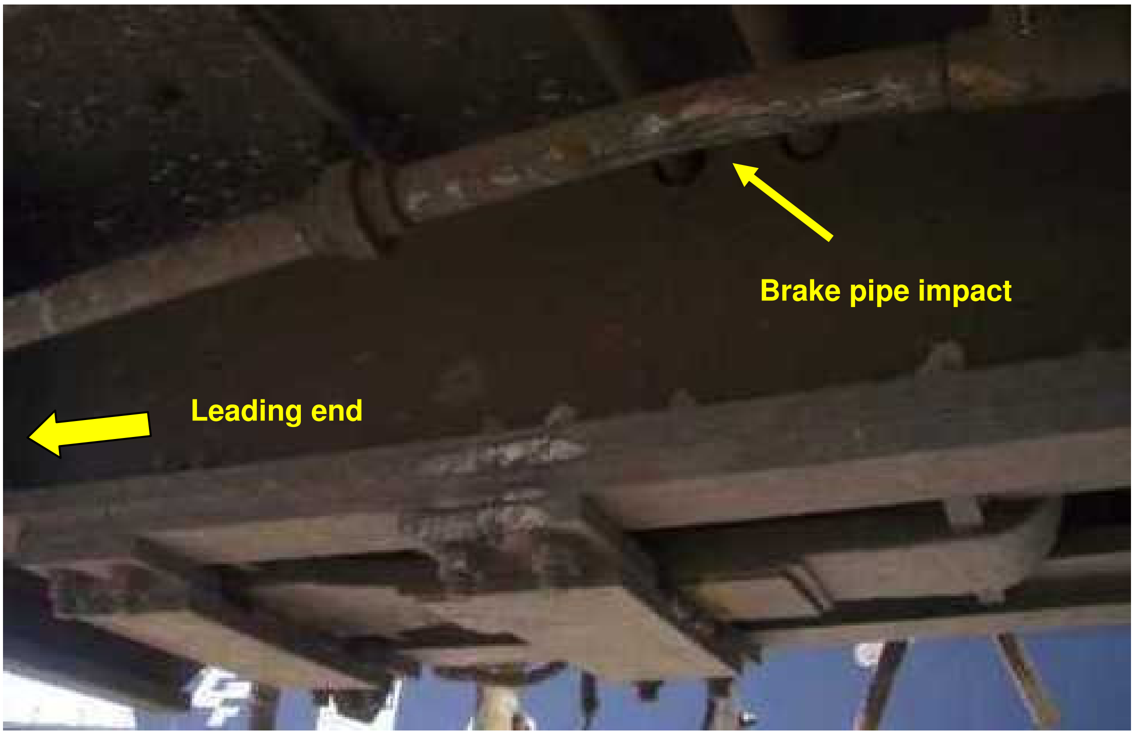

Figure 5 – Impact to the brake pipe under the body of the ballast wagon

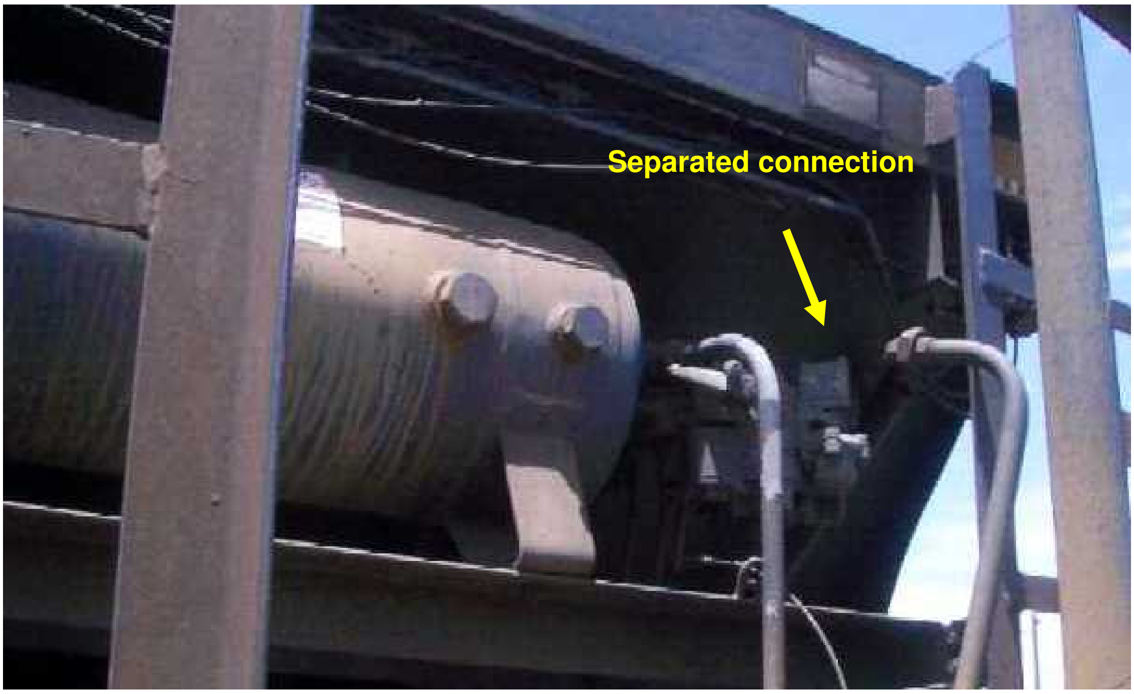

Figure 6 – Separation of brake pipe fitting, leading end of ballast wagon NDFF2223S

The state of the load of the derailed ballast wagon prior to the incident could not be ascertained by inspection. The wagon had been derailed for some distance resulting in spillage and redistribution of the load.

All wheels of the ballast wagon were well-worn but no wheel was condemnable. There was relatively little damage to the wheel treads from running whilst derailed.

All bogie springs were in position and intact and when measured at the depot, side bearer clearances were within the required range of 10 mm to 14 mm for ANZR bogies.

The body centre-plates and bogie centre-bowls exhibited damage sustained during the incident as a result of partial or full disengagement; however, it was evident that they had been in good condition prior to the incident.

Plough wagon NZBF1045S

All wheels (WPR2000 profile) of the derailed ballast plough wagon showed little wear from new. There was relatively little damage to the wheel treads from running whilst derailed.

All bogie springs were in position and intact and when measured at the depot, side bearer clearances were within the required range of 10 mm to 14 mm for ANZR bogies. Both body centre-plates and bogie centre-bowls exhibited damage sustained during the incident, but it was evident that they had been in good condition prior to the incident.

The body and under-frame had suffered localised damage during the incident. The plough blade had suffered considerable distortion and the right-hand-side leading side-bearer body wear plate had suffered severe impact damage.

2.1.8 Other wagon information

ARTC was unable to provide technical drawings and other requested technical information for the two derailed wagons. Accordingly, the investigation sought information from the previous owners of the wagons, RailCorp[4], which advised that the wagons had been vested to ARTC in 2004. RailCorp, were able to provide drawings of the NDFF ballast wagon but were unable to provide any drawings or other technical materials in relation to the NZBF plough wagon.

The NDFF ballast wagon and NZBF plough wagon are both categorised in the ARTC Train Operating Condition Manual as Class C rolling stock. The rolling stock data sheet also notes that the NDFF wagon is not to be run with excessive load imbalance, citing the potential for derailment.

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[4] RailCorp (Rail Corporation NSW) provides metropolitan and long distance passenger rail services in NSW. RailCorp also maintains the metropolitan rail network and provides access to freight operators in the metropolitan area.

2.2 Operations

2.2.1 Train speed

The maximum permitted speed for this line segment was 130 km/h and there were no Temporary Speed Restrictions in force at this location. Individual trains may be further limited in speed depending on their class, rolling stock classification and other criteria.

The ARTC *Code of Practice for Operations and Safeworking* specifies the maximum train speeds on the interstate network based on the 'train class' of super premium, premium, high, standard, low or other. The maximum authorised speed is then specified as the lower of the train class speed, the maximum speed allowed by the classification of the rolling stock and a number of other criteria.

The rolling stock classification system is specified within Section 23 of the ROA (Railways of Australia) Manual. The ROA Manual specifies a maximum permitted speed of 80 km/h for wagons with an 'F' as the fourth character within their classification, as was the case for all wagons being hauled. ARTC has also advised that the permitted speed for this ballast train between Melbourne and Albury was 80 km/h.

The Hasler speed chart from the lead locomotive recorded that after the train recommenced its journey following stopping for repairs, the indicated speed varied around 80 km/h. About five minutes before reaching Longwood, the speed increased, peaking at about 90 km/h for a short time before reducing to about 82 km/h on the approach to the Down Street level crossing.

2.2.2 Distance to stop

The train came to a stand with the lead locomotive about 470 metres past the southern end of the Pranjip Creek railway bridge located at 136.0 rail kilometres from Melbourne. Utilising the Hasler speed chart, the investigation estimated that it took the train approximately 450 metres to come to a stand after the loss of brake pipe pressure. This positions the lead locomotive on or just after the railway bridge when the train lost brake pipe pressure and the last two wagons around 230 metres past the Down Street level crossing.

2.2.3 Driver and assistant reports

The locomotive driver and driver's assistant both reported signing-on at 0600. After coupling the locomotives to the wagons, the crew prepared the train including making visual checks and conducting a brake test.

The driver reported that the train departed Violet Town at about 0700 and stopped at Euroa[5] to reconnect a loose locomotive jumper cable.

Around Longwood, the driver noticed that the lead locomotive was riding rough and then noticed the brake pipe pressure starting to drop at around the "136 kilometre peg". The driver reported keeping the train stretched to avoid any run-in[6].

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[5] The Hasler speed chart indicated that the train had not yet reached Euroa and stopped about four kilometres after departing Violet Town.

[6] Run-in is a term used to describe the compressive slack action of couplers and drawgear between wagons.

The assistant reported that as they traversed the road crossing in Longwood (Down Street), the lead locomotive kicked and rocked. Just after the bridge (Pranjip Creek), the driver said to the assistant that they had lost air. The assistant looked back and saw a cloud of dust.

2.3 Weather

At the time of the incident the weather was fine with little or no cloud and a temperature of about 12 degrees Celsius.

The two weather recording stations closest to Longwood are located at Strathbogie and Mangalore. The Strathbogie station recorded 114 mm of rain during November and 10 mm in the 10 days of December prior to the incident. The Mangalore station recorded 86 mm in November and 4 mm in the first part of December. The most recent heavy falls were on 20 November with an average rainfall of 28 mm recorded across the two stations.

2.4 Post-incident track inspection

2.4.1 General rail and track condition

There were no significant or obvious geometric defects visually identified in the track approaching the Down Street level crossing. At the level crossing and beyond, there were indications of geometric irregularity.

The level crossing itself, located at 136.541 rail kilometres from Melbourne, was sealed with bitumen, as shown at Figure 7.

Figure 7 – Track through the Down Street level crossing (photograph enlarged to show detail and may exaggerate track irregularities)

2.4.2 Ballast condition

The ballast on the Melbourne side of the Down Street level crossing was fouled with mud, particularly around the left-hand (Up) rail. This fouling was particularly evident between the crossing and the point of flange-climb.

Figure 8 – Ballast condition on Melbourne side of Down Street level crossing, looking south

The location was re-inspected in November 2009 after its restoration. The ballast was found to be fouled with mud in a similar location to that previously identified at the incident site. There was also evidence of mud pumping[7] resulting in mud and moisture in the formation rising to the surface and indicating poor drainage.

Figure 9 – Repaired track 10-15 metres south of the level crossing (photograph November 2009)

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[7] Mud pumping is when muddy ballast particles and subgrade materials are pumped to the surface by the up and down action of the roadbed during the passing of a train.

2.4.3 Derailment indications

There was clear evidence of flange-climb on the right-hand-side rail when viewed in the direction of travel, commencing about 25 metres after the southern edge of the sealed level crossing. The flange drop-off point and the corresponding tread corner drop-off on the left-hand rail were also clearly evident.

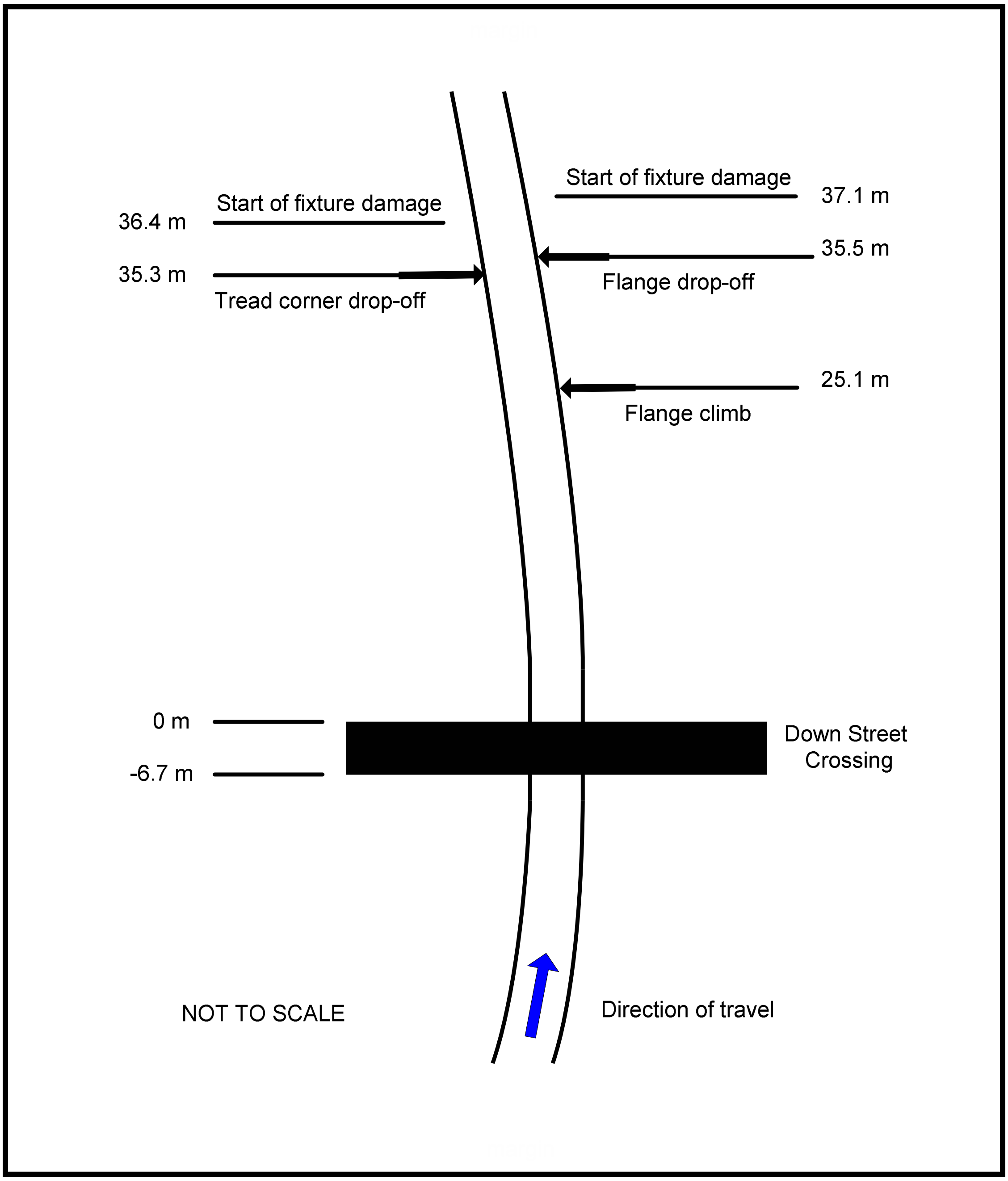

Figure 10 – Critical points of the first derailment

Figure 11 – Flange mark on right-hand rail head extending about 10 metres to the point of drop-off

2.4.4 Track and infrastructure damage and other indications

Initial damage to sleepers and track fastenings was light. Track damage commenced about a metre after both wheels of the first wheel-set had derailed. There was also evidence of crushed sleeper and ballast material on the railheads indicating on-rail wheels trailing the derailed wheels.

Figure 12 – Typical wheel marks after initial derailment and prior to the first rail fracture

The key incident site features following the derailment of the first wheel-set are shown at Figure 13.

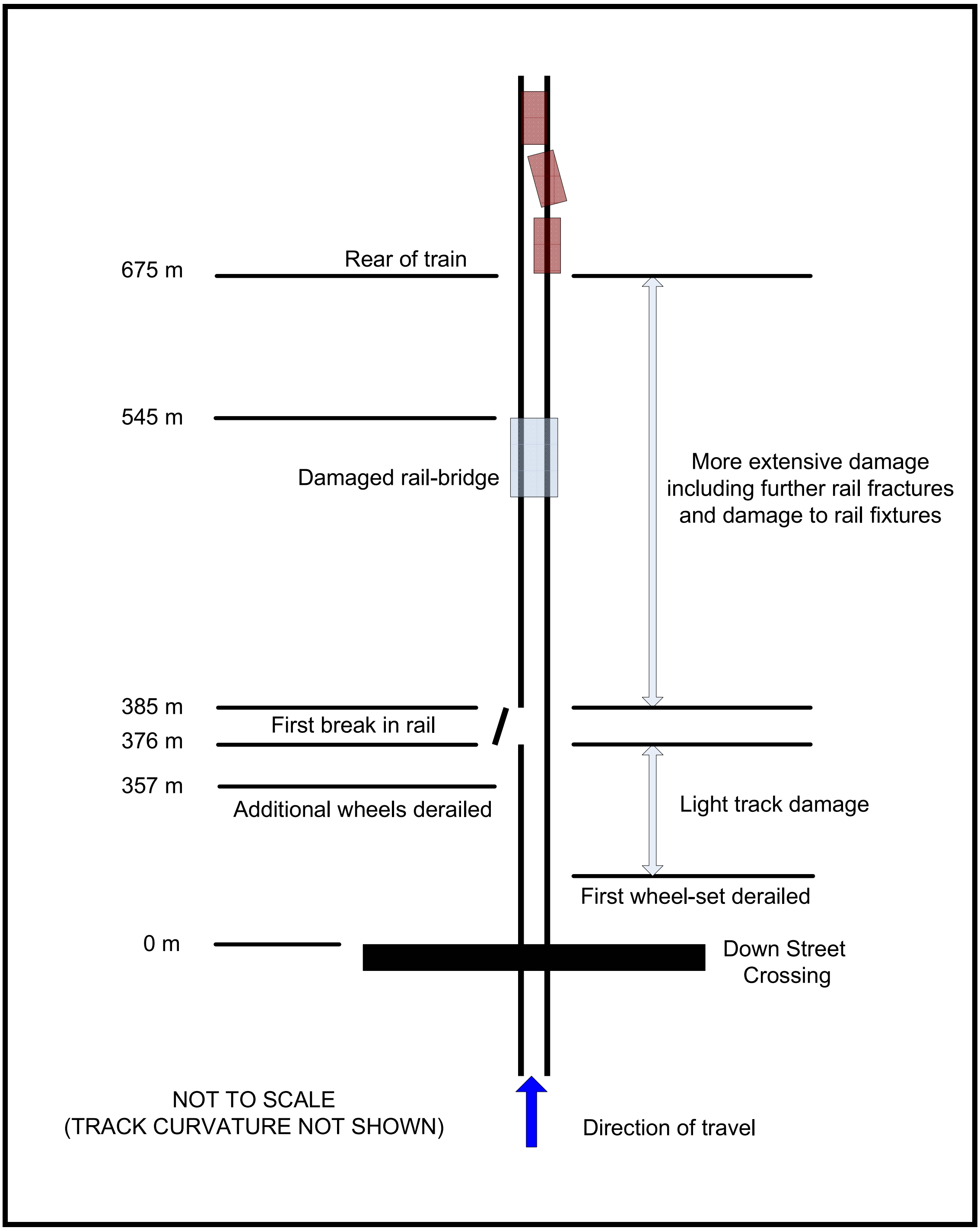

Figure 13 – Location of key features following the derailment of the first wheel-set

Following the derailment of the first wheel-set, the track damage remained light and consistent for over 300 metres with the track transitioning from a left-hand to a right-hand curve.

About 357 metres from the southern edge of the Down Street level crossing, there was evidence of additional wheels having derailed. A further 19 metres along, the left-hand rail was fractured resulting in a gap in the rail of about nine metres in length.

Figure 14 – First rail fracture, about 376 metres after the Down Street level crossing

Beyond this initial fracture and gap in the left-hand rail, the track was out-of-gauge (wide) with the left-hand rail dislodged from its fixtures. The left-hand railhead was clean whereas there was irregular crushed ballast on the right-hand railhead. In this section of track prior to the railway bridge there were additional fractures in the left-hand rail.

The railway bridge passing over Pranjip Creek had suffered significant damage. The damage on the northern, approach-end of the bridge was relatively light, apart from impact damage on the right-hand-side concrete abutment. There was also impact damage to the inner fixtures of the left-hand rail, although further onto the bridge the track was within gauge. The southern end of the railway bridge suffered severe damage to the sleepers and impact damage to the right-hand-side concrete abutment.

The investigation noted that guardrails[8] were not fitted to the railway bridge. This is consistent with ARTC policy. Guardrails are sometimes fitted to a bridge to contain derailed wheels and help prevent rolling stock from falling off the bridge, although it is acknowledged that their use on this type of bridge has not been common practice in Victoria for at least 20 years. In this instance, the wagons remained on the bridge and the absence of guardrails would not appear to have significantly impacted the outcome.

Beyond the bridge, the track was severely damaged and consistent with both wagons having all wheels derailed.

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[8] Railway bridge guardrails are constructed by fixing a rail inside each running rail.

Figure 15 – Damage to the approach end of the railway bridge

Figure 16 – Damage to the departure end of the railway bridge

2.5 Infrastructure

2.5.1 Track Management

ARTC is accredited by PTSV (Public Transport Safety Victoria) as the Rail Infrastructure Manager for the standard gauge corridor between Melbourne and Albury. ARTC contracts Downer EDI Works to undertake the day-to-day inspection and maintenance of the track.

2.5.2 Track inspections and standards

The DIRN in Victoria is maintained under the ARTC *Track and Civil Code of Practice SA/WA & VIC*. The code specifies minimum inspection requirements for main lines as including track patrols at intervals not exceeding seven days, on-train inspections at intervals not exceeding six months, track geometry car inspection or equivalent at intervals not exceeding four months and unscheduled inspections in response to driver reports or events where track geometry may have been significantly affected.

The geometry defect intervention limits and response guidelines are defined within the ARTC code. The response requirements are summarised below:

Response Category	Inspect within	Re-inspect within	Action
E (Emergency)	Prior to next train	-	Stop train, repair, see Note (3)
U1 (Urgent Class 1)	12 hours	48 hours	See Note (1)
U2 (Urgent Class 2)	48 hours	7 days	See Note (1)
P1 (Priority Class 1)	7 days	28 days	See Note (1)
P2 (Priority Class 2)	14 days	Inspect by exception on regular patrols	

Note (1)
Inspect defect within the defined period; and repair the defect, or

- assess the defect and apply an appropriate TSR (Temporary Speed Restriction), or
- if the defect is found to be spurious, reassign to an appropriate defect category and apply a TSR if required.

If a TSR is applied, re-inspect within the defined period, assess rate of deterioration and continue to re-inspect defect until repaired.

Note (2)
Combination of faults at U1 or U2 levels – if faults occur within 20 metres of each other, apply TSR at appropriate lower speed band and inspect within 24 hours. Then re-inspect every 24 hours until repaired.

Note (3)
Stop trains as a precaution, then inspect and assess. Various options are given for repairing the track and piloting over a defect in the interim.

The current RISSB (Rail Industry Safety Standards Board) standard covering track inspection and response is the *Australian Standard Rail Networks Code of Practice Volume 4 Track, Civil and Electrical Infrastructure, Part 3: Infrastructure Guidelines* which was released in July 2009 and after the incident. The geometry defect response requirements of the ARTC code are generally the same or exceed the requirements of this latest RISSB standard.

Combinations of irregularities

The ARTC code notes that the defined responses "… are based on isolated geometric defects and that a more stringent response than that mandated by the geometry alone may be necessary if deterioration of the infrastructure both at the defect and on adjoining track is in evidence (refer to *Volume 4, Part 1 – Assessment: Combinations of defects*).". This is understood to be a reference to the industry code of practice, as discussed below.

The relevant industry code extant at the time of the incident was the *Code of Practice for the Defined Interstate Rail Network Volume 4, Track, Civil and Electrical Infrastructure Part 1: Infrastructure Management* dated January 2003. This code was superseded in July 2009 by the *Australian Standard Rail Networks Code of Practice Volume 4 Track, Civil and Electrical Infrastructure, Part 1: Infrastructure Management* published by RISSB. On the matter of combinations of defects, both codes are identical and state:

"Where condition standards or assessment rules for the infrastructure condition have been detailed in Volume 4, Part 3 of this Code they refer to single isolated defects or irregularities. In practice defects may occur in combination or repetitively along the infrastructure.

Where combinations of defects or irregularities occur, the minimum response should at least be the most stringent or restrictive response appropriate to any one of the individual defects or irregularities. A more restrictive response may be required because of the interactive and cumulative effects of combined or repetitive defects. Combinations of defects or irregularities none of which individually require action to be taken (as detailed in Volume 4, Part 3) may jointly require action to provide for safe operations.

The judgment of the worker carrying out the inspection and assessment plays an important role in deciding what actions are required in these situations. The requirement for competent workers with the practical experience and ability to make such judgmental decisions is essential."

2.5.3 Downer EDI Works processes and procedures

Track maintenance is managed by Downer EDI Works using the Maximo® asset management database. This system is used to record defects and their treatment including the raising of work orders.

Downer EDI Works has procedures addressing inspection frequencies and the management of track defects. Inspection and patrol frequencies were found to either meet or exceed the ARTC Code of Practice. The treatment of defects varies depending on the method of identification. Those defects identified by track geometry car inspections are to be managed in accordance with the ARTC code. Faults identified through other inspections and patrols are managed using a different fault categorisation and remedial action system.

2.5.4 Track geometry recording

The measurement and recording of track geometry on the ARTC network was made by the track recording train which is colloquially referred to as the “AK cars”. The track recording train measured the track geometry through Longwood in June and October prior to the incident. In each case twist defects were the only defect type recorded in the area of interest. Twist is the variation in track cross-level over a defined distance, typically two metres or 14 metres.

The section of track was measured on 25 June 2008. The exceedence report for the recording period indicates a long (14 metre base) twist defect of -37 mm at 136.511 kilometres, with a response category of U2 (see section 2.5.2).

The section was again measured on 12 October 2008, about two months prior to the incident. The exceedence report for this period indicates two long and two short (two metre base) twist defects just prior to the flange climb. The highest priority (category U2) defect was a long twist of -38 mm at 136.516 kilometres. A long twist defect of -33 mm at 136.510 kilometres and two short twist defects in this area were designated response category P1. The track maintenance contractor subsequently supplied later records indicating that the U2 defect at 136.516 kilometres had been repaired on 31 October 2008 but that there existed a long twist defect of -37 mm at 136.511 kilometres.

When assessed against the ARTC code, none of the defects identified by the track recording train during the preceding months indicated a need for emergency action. The investigation noted that had a TSR of 80 km/h been imposed as a temporary remedial measure, the response category would have been reduced to P2 which requires no specific action other than inspections. This would not, however, have affected the authorised speed for the ballast train operation.

2.5.5 Other inspections and patrols

An on-train inspection was conducted from the XPT on 10 December, the day before the incident. For the Benalla-to-Seymour section, the inspection noted the condition as being fair. No specific issues were identified at or close to the point of derailment; the nearest being the identification of ride issues at 136.400 kilometres.

A track patrol through the section was conducted on 9 December, two days prior to the incident. No issues were identified in the area of the incident during that patrol or on any other patrol in the three months prior.

There were no reported unscheduled inspections in the vicinity of the Down Street level crossing in the three months prior to the incident.

2.5.6 Post incident track measurement

Following the incident, a KRAB[9] trolley was used by ARTC to record the geometric condition of the track. The KRAB trolley is a light-weight device which measures a number of geometric parameters of the track in an unloaded state. In this instance, the KRAB recordings were not corrected for potential depression under load. Track depression measurement had been made impractical due to track repair works being commenced shortly after the derailment and prior to the investigation’s arrival on site; cutting the line on the northern side of the incident site.

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[9] KRAB is a specialist device for measuring track geometry, manufactured by KZV s.r.o., Prague.

The investigation was supplied with the raw KRAB data at 0.25 metre intervals and transcribed, tabulated data at one-metre intervals. The transcribed data identified a series of U2 twist defects over a 14 metre base, with a highest twist value of -40 mm at a starting point at 136.521 kilometres, about nine metres prior to the recorded point of flange climb. Cross-level defects were also identified within the supplied data in those instances where absolute cross-levels exceeded design values by more than 15 mm.

Considering the measured cross-levels in the context of the actual track curvature through the section, the superelevation[10] was found to generally exceed the equilibrium cant[11] for an 80 km/h train, with an average cant excess[12] of around 20 mm for the nominal 1200 metre radius curve. Through and just after the crossing, the track straightened for a short distance but with the superelevation remaining relatively high, giving a peak transient cant excess of 70 mm for the ballast train.

The straightening of the track through and shortly after the level crossing, as indicated by the versine[13] data, is a deviation from the design curvature and is also effectively a track irregularity. The track had a left-hand curve of around 1200 metres radius prior to the crossing, straightened, then returned to a left-hand curve after the crossing.

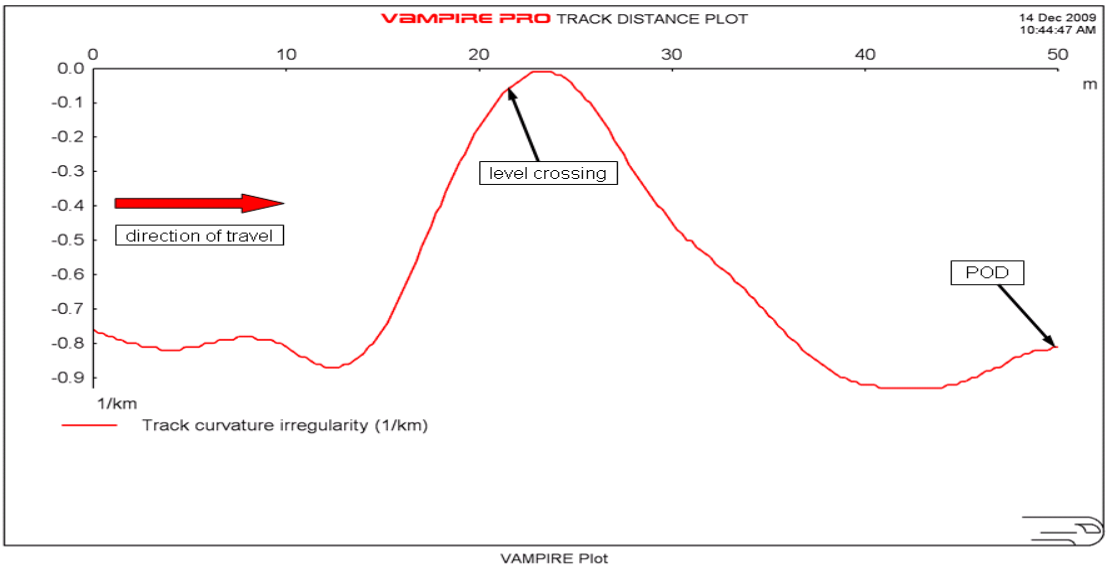

Figure 17 – Track curvature irregularity in the approach to the point of flange climb (marked POD)

Also of note in the track data was a discernable dip in both rails after the level crossing. The peak-to-trough variation in rail height was around 25 mm for both rails and was measurable as a 25 mm offset over a chord of about 10 metres. The ARTC code specifies the measurement of top irregularities over 4-metre and 20-metre chords. This dip in the track would not be identified under the code as a top irregularity requiring urgent or emergency action.

When assessed against the ARTC code, none of the defects identified in the unloaded track geometry and considered in isolation would flag a requirement for emergency action.

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[10] Superelevation is used on curves to facilitate higher railway speeds, the outer rail on the curve being raised above the inner rail. Superelevation is measured as the height of the outer rail above the inner, also referred to as cant.

[11] For a given track curvature and train speed, the equilibrium cant is that at which the right and left wheels are equally loaded.

[12] Cant excess exists when the actual cant is greater than the equilibrium cant for the train speed being considered.

[13] Versine is the measured offset of the rail at the midpoint of a chord taken across a piece of curved rail. The versine measurement can be used to estimate track radius.

2.6 Dynamic modelling of wagon-track interaction

2.6.1 Modelling

The investigation engaged specialists in dynamic modelling to gain greater insight into possible wagon behaviours leading to the derailment. The VAMPIRE®[14] software was used to examine the dynamic response of the ballast and plough wagons to the track geometry. The specific aims of the modelling were to inform the investigation about the wagon and the wheel most likely to have first derailed and the factors contributing to the development of flange-climb conditions at that wheel.

2.6.2 Input data, assumptions and sensitivity

ARTC was unable to furnish requested technical information on the derailed wagons. Accordingly, rolling stock models were based on technical data obtained from third-party sources and supported by engineering judgment.

The baseline track model was developed using the post-incident KRAB trolley data which was a measure of the track geometry in an unloaded state. Further simulations were then conducted to assess the implications of track depression which may have occurred under the dynamic load of the train.

The analysis considered the sensitivity to an increased and offset payload in the ballast wagon and variations in wagon inertia, wheel tread conicity and train speed.

2.6.3 Conditions needed for derailment

The key outputs of the VAMPIRE® modelling which provide an indication of the potential for derailment are the percentage of wheel unloading, the ratio of lateral-to-vertical wheel-rail force (L/V) and the lateral displacement of each wheel-set with respect to the track. For flange-climb to occur at the point recorded, wheel unloading would be expected to be high (typically in excess of 80 per cent), the L/V quotient in excess of the derailment value (assumed for this investigation as a value of 1.2) and the wheel-set lateral displacement must be sufficient for the wheel flange to contact the rail.

2.6.4 Wagon most likely to have derailed first

Initial VAMPIRE® calculations using unloaded track geometry did not yield sufficient dynamic response required for derailment. Track depression was required to give the possibility of flange-climb at the incident location. The potential for derailment of the ballast wagon was also significantly greater with an increased and offset payload and with the optimisation of other variables, although the individual contribution of each variable to the derailment could not be ascertained.

For the identified and optimised conditions, the simulations demonstrated that the most likely wheel to have first derailed was the leading right-hand wheel of the ballast wagon. For these conditions, there was good correlation between the model and the point of flange climb identified in the field.

For all conditions and simulations, the plough wagon results indicated it to be safe against derailment.

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[14] VAMPIRE® simulation software enables dynamic modelling of rail vehicles and permits the study of vehicle response to actual track geometry or other specific inputs.

The simulations identified that the derailment condition was highly sensitive to wheel-tread conicity and that the onset of spring coil binding could rapidly increase the likelihood of achieving flange-climb conditions.

2.6.5 Sensitivity to small variations in speed

Noting that the indicated speed of the train was slightly greater than authorised, simulations were performed for a range of speeds between 83 and 77 km/h to assess whether the likelihood of derailment was sensitive to small changes in train speed, including a reduction. The results of this modelling indicated almost no change in the flange-climbing quotient within this range and little change in the risk of derailment, suggesting that a slight over-speed is unlikely to have contributed to the derailment.

2.6.6 Wagon dynamic response to level crossing

The simulations showed that significant response was initiated in both wagons as they passed across and departed the level crossing, with the ballast wagon suffering significant roll motion. This is consistent with the observations from the train crew that the locomotive had kicked and rocked as it passed through the crossing.

The simulations indicated that the roll motion of the ballast hopper was sustained to derailment and that a roll to the left coincided with the flange-climb.

2.7 Responsibilities for rolling stock safety management

2.7.1 Background

This train operation was what is commonly referred to in the rail industry as “hook-and-pull”. The motive power provider is contractually responsible to ‘hook’ on to the rolling stock supplied by the client and ‘pull’ it to an agreed destination. The train operator retains obligations for the operation as a whole under rail safety legislation in Victoria. Rail contractors and rail safety workers supporting the operation also have safety duties under the legislation.

2.7.2 SIA partners

Through various contractual arrangements the SIA partners, including ARTC, were responsible for supplying the wagons to be hauled. These responsibilities included providing the wagons in a “fit-for-purpose” condition and loading the wagons.

ARTC is accredited by PTSV as a rolling stock operator with the accreditation limited to road/rail vehicles used “For the purposes of monitoring the condition and/or performance of the track.”. The scope of the accreditation does not extend to other rolling stock such as ballast wagons and this is why third party accredited rolling stock operators such as SSRS are used in “hook-and-pull” arrangements.

2.7.3 South Spur Rail Services

Through standing agreement, SSRS had limited its contractual obligations for the wagons to general pre-departure checks and the operational management and care of the wagons during haulage. SSRS did not provide evidence of any audit or other system to otherwise assure itself that the wagons were fit-for-purpose or correctly loaded.

2.7.4 SSRS accreditation

As required to undertake this operation in Victoria, SSRS was accredited by PTSV as a rolling stock operator. The accreditation states that SSRS is "Permitted only to operate diesel locomotive hauled rolling stock which has been leased and maintained from third-parties.".

Prior to the incident, SSRS was last accredited on 26 June 2008. The accreditation documentation supporting the submission included a safety management plan, risk assessment, details of mitigations and supporting procedural documentation. The risk register submitted as part of the accreditation process identified failure to maintain rolling stock to standard as a hazard. Identified risk controls included the existence of maintenance agreements with rolling stock providers and train inspection prior to departures.

While not considered directly contributory to this incident, the investigation found that parts of the documented safety management system did not reflect how SSRS operated within Victoria.

2.8 Recent Australian Transport Safety Bureau investigations

2.8.1 Roopena derailment on 22 May 2007

The ATSB (Australian Transport Safety Bureau) investigated the derailment of a similar ballast train in South Australia on 22 May 2007. The ballast wagons were different to those involved in the Longwood incident, however, similarities in the case include the existence of track irregularities, rolling stock response to the track geometry and the flange-climb mechanism of derailment.

The ATSB concluded[15] that interaction between wagons and track had led to body-roll, unloading of the leading right-hand-side wheel of a ballast wagon and consequent flange climb and derailment. A number of safety issues were identified in the report, including that:

"It is unlikely that the combined effects of the track geometry were considered when assessing a track speed suitable for safe rail operations, especially considering that the horizontal alignment defect was below the documented defect limit and associated response codes.", and

"It is unlikely that the dynamics of poorer riding rolling stock were considered when assessing the track geometry defect and determining a suitable speed limit for train operations.".

2.8.2 Winton derailment 21 July 2008

The ATSB also investigated a flange-climb derailment of a freight train near Winton in Victoria, on the North East line of the DIRN. The wagon believed to have first derailed was loaded with two coils of steel, each weighing about 27 tonnes.

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[15] The full ATSB report RO-2007-003 on the Roopena incident can be found at http://www.atsb.gov.au/rail.aspx

The ATSB concluded[16] that a series of track irregularities caused the wagon body to roll with sufficient force to unload the leading right wheels close to the point of derailment. A number of safety issues were identified in the report, including that:

"The ARTC Code of Practice does not clearly address the possibility that a series of track irregularities, even minor ones which do not exceed intervention limits, could cause undesirable harmonic response in some rail vehicles."

In reporting on the Winton investigation, the ATSB also examined similarities with the Roopena derailment and an earlier derailment in Benalla on 23 September 2004. The ATSB concluded that:

"In all three derailments, the wagons involved were relatively short, had very rigid bodies, had a relatively high centre of gravity when loaded, travelled on bogies that incorporated gap style side-bearers and were rated for a maximum speed of 80 km/h. Similarly, each wagon derailed while traversing track irregularities that either did not exceed the intervention limits or had been assessed as suitable for rail traffic travelling at 80 km/h …. In each case, investigation found a series (or combination) of track irregularities caused the wagon to roll with sufficient force to cause wheel unloading such that the risk of flange-climb increased at the point of derailment. It was also found that inspection and assessment of the track irregularities was unlikely to have considered the dynamics of poorer riding rolling stock."

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[16] The full ATSB report RO-2008-009 on the Winton incident can be found at http://www.atsb.gov.au/rail.aspx

3. ANALYSIS

3.1 The incident

3.1.1 Sequence of events

It is probable that the derailment of the ballast train at Longwood was the result of the leading right-hand wheel of ballast wagon NDFF2223S climbing the right-hand rail about 25 metres after passing through the Down Street level crossing. This wheel then ran along the rail-head for about 10 metres before both wheels on the leading wheel-set became derailed to the right.

This conclusion is supported by dynamic modelling which found that the leading right-hand wheel on the ballast wagon was the most likely to derail at the point of flange-climb identified at the incident site. Also supporting this scenario was the estimated location at which the brake pipe integrity was breached on the ballast wagon.

Subsequent to the derailment of the first wheel-set, the sequence of events is less clear and of less causal importance.

It is possible that the lead axle of the ballast wagon was the only derailed wheel-set for some time. During this time and with the leading bogie skewed, the brake pipe beneath the wagon hopper was impacted, resulting in the failure of the brake pipe fitting at the leading-end of the wagon and the loss of brake pipe pressure. Evidence suggests this happened about 200 metres after the initial flange climb.

Soon thereafter, another wheel-set derailed, probably the trailing axle of the lead bogie on the ballast wagon. A short time later with all wheels of the ballast wagon lead bogie now derailed, it is probable that impact of the derailed wheels with the rail and its fixtures fractured the left-hand rail and caused its dislodgement and movement.

Following the fracture, it is possible that, while all wheels of the leading bogie of the ballast wagon remained derailed, following bogies may have been in a derailed state with the left-hand wheels inside the left rail running edge and the right-hand wheels still tracking the rail.

As the track was in-gauge on the central portion of the bridge, it is possible that some or all of the trailing bogies may have re-railed their left-hand wheels, but with the leading bogie of the ballast wagon remaining derailed. However, at some point while traversing the bridge and perhaps contributed to by the impact of the derailed bogie with the right-hand concrete abutments, all wheels of the ballast and plough wagons have become derailed and remained so until the train came to a stop.

3.1.2 Mechanism of derailment

The derailment was the result of a wheel climbing the right-hand rail about 25 metres after the level crossing. Modelling by the investigation supports this and confirms that the pre-conditions for flange-climb could be established at the ballast wagon. The modelling also identifies the leading right-hand wheel of this wagon as the most likely to derail.

The establishment of flange-climb conditions at this wheel was the result of the wagon’s response to a combination of geometric features in the track. It is probable that the track geometry through and departing the level crossing established a dynamic response in the wagon including body-roll which then aligned and combined with the wagon’s response to a significant track twist defect.

That the last ballast wagon, the second last wagon in the consist, derailed rather than ballast wagons ahead was probably due to it having only the relatively light-weight plough wagon attached behind, allowing this ballast wagon greater freedom to develop unwanted dynamic behaviour.

3.2 The ballast wagon

3.2.1 Ride performance

In addition to its running speed, a wagon’s behaviour and performance will be influenced by many factors such as its geometry and construction, its load characteristics and its bogie and suspension configuration. The NDFF ballast wagon is a short wagon with a relatively high centre of gravity when loaded and incorporates plain (gap type) side bearers. Evidence of spring coil binding in the ballast wagons of this train also suggests that the suspension has at some time(s) reached its limits. Because of these characteristics and its ride limitations, the NDFF wagon has a maximum permitted speed of 80 km/h.

These wagon characteristics are similar to those of three recent ATSB investigations into flange-climb derailments on the DIRN. ATSB commented that “In all three derailments, the wagons involved were relatively short, had very rigid bodies, had a relatively high centre of gravity when loaded, travelled on bogies that incorporated gap style side-bearers and were rated for a maximum speed of 80km/h.”. In each of these recent cases, the train was also “… traversing track irregularities that either did not exceed the intervention limits or had been assessed as suitable for rail traffic travelling at 80 km/h.”

3.2.2 Wagon loading

The ballast wagons were fully loaded. However, the investigation could not confirm the actual pre-incident weight of the load on wagon NDFF2223S, primarily due to the absence of loading records. Similarly, the evenness of the load could not be ascertained due to load shift during the derailment.

Dynamic modelling indicated that overloading and load asymmetry can increase the likelihood of derailment including contributing to the earlier onset of spring coil binding and wheel unloading. However, the investigation was unable to ascertain whether or the extent to which these factors may have contributed in the incident.

It is unlikely that the pre-departure checks would have identified uneven or excessive ballast loads except for more extreme cases. Assuring the correct load therefore rested with the land-based loading service which was not supported through the provision of guidelines nor supervised by rail personnel. The loading systems at the quarry also had the potential to deliver an incorrect load.

The methods used by the quarry to assure the correct amount of ballast is loaded could be improved. The weighing system fitted to the front-end-loader relies to a large extent on human intervention and would be enhanced by a formal and/or automated method of weighing and recording. The front-end-loader weighing system is also not adequately calibrated and a formal regime of calibration would significantly improve confidence in the system.

The current loading method also relies on the experience of the operator to achieve evenness. Consistency in loading could be enhanced by introducing a formal system for checking the evenness of the load.

The investigation also noted that the ARTC had not provided the quarry with documented guidance on rail safety requirements. Given the proximity of the siding to the running line, the loading operation presented a risk to other rail traffic (for example, should ballast overthrow occur).

3.3 Track

3.3.1 Defects and monitoring

The track geometry exceedence records for October 2008 identify a twist defect which, in isolation, would not normally be sufficient to cause derailment. It is, however, possible that the defect had worsened prior to the incident particularly given the fouled condition of the ballast and the rainfall during the preceding month.

The measurement of the track in an unloaded state was made after the incident and a long twist defect of similar magnitude and around the same location identified. Noting the condition of the ballast, it is probable that the actual geometry of the track during the ballast train's transit was affected by the dynamic action of the train.

Other track inspections were conducted in the days leading up to the derailment; a track patrol on 9 December and an on-train inspection on 10 December. That neither of these inspections identified issues at or close to the point of derailment raises a question as to the adequacy of the inspection regime.

This inability of the visual inspection regime to identify potential issues for rolling stock with limited ride performance has also been identified in other investigations. Commenting on three other flange-climb derailments on the DIRN, the ATSB noted that the "… inspection and assessment of the track irregularities was unlikely to have considered the dynamics of poorer riding rolling stock."

3.3.2 Combination irregularities

The Longwood derailment was the result of wagon response to a combination of track irregularities. The track geometry across the Down Street level crossing was found to induce significant motion in the ballast wagon. This response motion then combined with the twist defect to establish the pre-conditions required for derailment.

Again these findings are similar to those of the ATSB for three other flange-climb derailments on the DIRN. The ATSB found that a combination of track irregularities caused wagon-roll, leading to wheel-unloading and increasing the risk of flange-climb.

The treatment of combination defects is only superficially addressed within the ARTC and RISSB track codes of practice; reliance being placed on the judgment of the worker carrying out the inspection. In this and previous instances, the inability of the inspection regime to identify the implications of combination irregularities, particularly for poorer-riding rolling stock, raises questions as to whether the current codes provide adequate guidance.

3.3.3 Ballast condition monitoring

The track maintenance regime includes a range of inspections including regular track patrols between more extensive track surveys using the track recording train. These intermediate patrols along with on-train inspections and train driver reports provide the opportunity for the identification and reporting of deteriorating track conditions including fouled ballast and mud holes. In this instance, the inspections one and two days prior to the incident did not identify this site as a potential hazard requiring remedial works.

At the time of the incident, the ballast was fouled with mud, potentially exacerbating geometric defects in the track. Inspections since the re-establishment of the track identified continuing issues with fouling and mud pumping suggesting underlying issues with formation drainage.

3.4 Operations

After its short stop for repairs, the train's recorded speed peaked at about 90 km/h which was 10 km/h over the maximum permitted speed for the operation. As the train approached the Down Street level crossing, the indicated speed had reduced to about 82 km/h; a minor exceedence of the authorised speed.

The investigation sought to ascertain whether the establishment of flange-climb conditions was sensitive to small variations in train speed. Modelling indicated that, in this instance, running at the authorised speed of 80 km/h would not have reduced the likelihood of flange-climb at the point of derailment. A more significant reduction in speed would have been required to reduce the risk of derailment.

3.5 Compatibility between rolling stock, track and speed

In this instance, a wagon which was considered fit-for-purpose and was travelling close to the authorised speed derailed on track which had satisfied the inspection regime.

The condition monitoring of the track, the setting of the authorised speed and the knowledge of the wagon ride qualities are all within the control of a single entity, the ARTC. The potential therefore exists for ARTC to review its management of compatibility across its rolling stock, track and operational requirements.

3.6 Safety governance

Under rail safety legislation, the accredited rolling stock operator had obligations to ensure the safety of the train operation. Supporting the operation were a number of rail contractors, rail safety workers and others who were involved in the set-up, maintenance and loading of the rolling stock. While legal safety duties are defined, the investigation found that, in practice, the relationships and roles of the parties were not always clear.

The investigation concluded that the nature of “hook-and-pull” operations has the potential to lead to an erosion of safety assurance through a series of contractual linkages, and promotes an arms-length relationship between the rolling stock operator and those supplying and loading wagons.

4. CONCLUSIONS

4.1 Findings

1. The train crew were appropriately qualified and medically fit to undertake their duties.

2. At the time of the derailment, the indicated speed of the train slightly exceeded that authorised.

3. The wagons that derailed were in a serviceable condition.

4. Unloaded track irregularities measured post-incident did not reach magnitudes which would require emergency intervention under the ARTC Track and Civil Code of Practice.

5. The derailment was the result of wheel-unloading and flange-climb.

6. The derailment location was affected by ballast fouling.

4.2 Contributing factors

1. Track inspections failed to identify the existence of track conditions which could prove unsafe for the passage of the NDFF wagon.

2. Track geometric irregularities combined to produce a dynamic response in the ballast wagon sufficient to create conditions conducive to flange-climb.

3. The ballast on the south side of the Down Street level crossing was fouled; contributing to the development of track geometric irregularities.

4. The configuration and ride behaviour of the loaded ballast wagon contributed to the nature of the wagon's response to the track geometric irregularities.

5. The authorised speed of the train was excessive when considered in the context of the track conditions and the ride characteristics of the ballast wagon.

5. SAFETY ACTIONS

5.1 Safety Actions taken since the event

The damaged track has been reinstated using concrete sleepers, the level crossing renewed and the track lifted 100 mm.

ARTC has advised that it is introducing more robust processes around mud-hole reporting, including the following specific actions:

1. Recording of mud holes in the asset management system.
2. Using static and under-load measurements to develop under-load exceedences.
3. Using under-load exceedences to determine authorised speeds.

5.2 Recommended Safety Actions

Where a safety recommendation is directed to ARTC, the recommendation may also be pertinent to other SIA partners, partner joint ventures or ARTC contractors.

Issue 1

The track inspection regime did not identify the presence of conditions which might lead to the derailment of rolling stock with particular ride characteristics such as those of the ballast wagon. Specifically, the system failed to adequately consider the implications on such wagons of a combination of geometric irregularities. The ARTC and RISSB codes of practice were also found to provide limited guidance for the assessment of a combination of defects.

The ATSB has also concluded that for three other derailments on the DIRN since 2004, a combination of track irregularities had resulted in short, rigid and relatively high centre of gravity wagons with plain (gap style) side-bearers developing a dynamic response sufficient to cause flange-climb.

RSA 2008074

That ARTC reviews its code of practice for the management, inspection and treatment of combination geometric irregularities.

RSA 2008075

That Downer EDI Works review its inspection practices.

RSA 2008076

That RISSB reviews its Australian Standard for the inspection and treatment of combination geometric irregularities.

Issue 2

The permitted operating speed for the NDFF ballast wagon was incompatible with the track conditions present at the time. This was in part due to a lack of appreciation of the existing track geometric conditions and in part due to a lack of appreciation of the ride behaviour of the wagon.

RSA 2008077

That ARTC reviews its system of managing the interaction between rolling stock and track including the determination of authorised speeds.

Issue 3

The method of loading ballast wagons at Violet Town could lead to uneven or excessive loads. There is no system of recording actual weights of ballast loaded into each wagon and there is no documented process for calibrating the loader's weighing system.

RSA 2008078

That Violet Town Quarries reviews its system of measuring and recording ballast loads on rail wagons.

RSA 2008079

That Violet Town Quarries formalises the calibration processes for the weighing system on loaders used to load rail wagons.

RSA 2008080

That Violet Town Quarries reviews its system of loading rail vehicles including methods of ensuring the evenness of loads.

RSA 2008081

That ARTC reviews the loading procedures at Violet Town and other rail ballast loading facilities servicing its network.

Issue 4

Violet Town Quarries was not provided with documented guidance on the loading of ARTC wagons. The siding used for loading is also in close proximity to a running-line which could potentially be obstructed as a result of the loading process.

RSA 2008082

That ARTC provides Violet Town Quarries and other ballast loading facilities as appropriate with documented guidance on loading ARTC ballast wagons and on rail safety requirements for operations being conducted on sidings located adjacent to running lines.

Issue 5

Those involved in rail operations have safety duties under Victorian legislation. The rolling stock operator has obligations to ensure the safety of the operation and rail contractors and rail safety workers supporting the operation have safety duties.

The nature of a “hook-and-pull” operation has the potential to extend the arms-length relationship between the operator and others involved in the rail operation, including those supplying the wagons and those involved in wagon loading operations.

RSA 2008083

That PTSV reviews the safety management systems of rail operators involved in providing crew and motive power (“hook-and-pull”) services to ensure that safety systems and their practical application adequately address operator safety obligations.