Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Rail Occurrence Investigation 2004/008
Final

Derailment of Pacific National Train 7MP5
Glenalta, South Australia

21 November 2004

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Abstract

At approximately 1006 on 21 November 2004, Pacific National freight train 7MP5 derailed in the Adelaide Hills near Glenalta. The freight train was travelling from Melbourne to Adelaide on the Defined Interstate Rail Network (DIRN), immediately adjacent to Adelaide's broad gauge metropolitan passenger rail network owned and operated by TransAdelaide.

Train 7MP5 consisted of four locomotives leading 72 freight platforms and wagons. The total train length was 1474m with approximately 2960 tonnes trailing the locomotives. A total of 10 platforms and wagons were derailed, with five obstructing the TransAdelaide track and four coming to rest down an embankment in private residential properties.

MEDIA RELEASE

Freight train derailment at Glenalta (SA) in November 2004

The placement of three empty rollingstock platforms immediately behind the locomotive was one of a number of key factors that combined to cause a freight train to derail at Glenalta, South Australia on 21 November 2004, according to an ATSB investigation report released today.

The Australian Transport Safety Bureau report states that the accident occurred after a single freight wagon bogie derailed over a set of points at Belair. A wheel contacted and lifted on top of a check-rail. The check-rail is designed to guide a wheel in the correct direction through the points. However, in this case the wheel was no longer retained by the check-rail and it travelled in the wrong direction subsequently derailing. No one was hurt as a result of the derailment. There was extensive damage to property, both public and private.

The ATSB engaged experts in advanced rail simulation modelling to test the hypothesis that the marshalling of the train and the placement of the empty platforms was the major factor in the derailment. The simulation provided compelling data to suggest that the weight configuration of the train was not of itself sufficient to cause the derailment. Other factors such as braking in such a way that compressive forces were accentuated, the suspension of the empty platforms, and a track geometry which resulted in wheel oscillation, also combined to induce the derailment.

The crew was not immediately aware that a bogie had derailed and the freight train continued for 3.7 km, progressively derailing other bogies before the derailment became apparent. The locomotive drivers realised that some wagons had derailed as the train reached Glenalta and immediately applied braking. The train finally stopped some 200m beyond the Glenalta railway station. A total of 10 freight wagons were derailed, with five obstructing TransAdelaide's passenger line and four coming to rest down an embankment into private residential properties.

While the report concludes that safety actions implemented immediately following the derailment are likely to have prevented any similar accidents, the investigation identified further opportunities to improve railway operational safety and made seven safety recommendations.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations. Accordingly, the ATSB also conducts investigations and studies of the transport system to identify underlying factors and trends that have the potential to adversely affect safety.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and, where applicable, relevant international agreements. The object of a safety investigation is to determine the circumstances to prevent other similar events. The results of these determinations form the basis for safety action, including recommendations where necessary. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

It is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and findings. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. 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.

Central to ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. While the Bureau issues recommendations to regulatory authorities, industry, or other agencies in order to address safety issues, its preference is for organisations to make safety enhancements during the course of an investigation. The Bureau is pleased to report positive safety action in its final reports rather than make formal recommendations. Recommendations may be issued in conjunction with ATSB reports or independently. A safety issue may lead to a number of similar recommendations, each issued to a different agency.

The ATSB does not have the resources to carry out a full cost-benefit analysis of each safety recommendation. The cost of a recommendation must be balanced against its benefits to safety, and transport safety involves the whole community. Such analysis is a matter for the body to which the recommendation is addressed (for example, the relevant regulatory authority in aviation, marine or rail in consultation with the industry).

The 24-hour clock is used in this report to describe the local time of day, Central Summer Time (CSuT), as particular events occurred.

EXECUTIVE SUMMARY

At approximately 1006 on 21 November 2004, Pacific National freight train 7MP5 derailed in the Adelaide Hills near Glenalta. Train 7MP5 consisted of four locomotives leading 72 freight platforms[1] and wagons and was travelling from Melbourne to Adelaide on the Defined Interstate Rail Network (DIRN). The total train length was 1474m, with approximately 2960 tonnes trailing the locomotives.

The derailment occurred over a 3.7km section of standard gauge track between Belair and Glenalta, located approximately 23 to 19 kilometres from Adelaide respectively. The track exhibits a steep 1 in 45 down gradient with a series of 190-350m radius curves, except for the standard gauge crossing loop located at Belair where the track is relatively straight with only a slight down gradient. Immediately adjacent to the DIRN is Adelaide's broad gauge metropolitan passenger rail network.

Freight train 7MP5 had negotiated a 240m radius left hand curve that leads immediately into the Belair crossing loop at 42 km/hr, 8 km/hr below the posted speed limit. While access to the crossing loop was via a right hand turn-out, the straight ahead main line route had been selected over the facing points. The point of derailment occurred at the turn-out, where markings indicated that a wheel had ridden over the check-rail allowing the opposite wheel to travel up the wrong side of the Vee.

Freight train 7MP5 continued for approximately 3.7km, progressively derailing other bogies. At Glenalta the derailing bogies struck a concrete pedestrian crossing panel and the bitumen road edge of a level crossing causing the freight wagons to jack-knife. The impact at the level crossing alerted the locomotive drivers who immediately applied braking, finally stopping the locomotives and four platforms of the first 5-unit wagon, approximately 200m beyond the Glenalta station. The brakes on the remaining wagons applied automatically due to loss of brake air pressure. However, the gradient and momentum prevented the wagons from stopping before colliding (jack-knifing) with the wagons coupled immediately behind the locomotives. A total of 10 platforms and wagons were derailed, with five obstructing the passenger track and four coming to rest down an embankment into private residential properties.

While no person was injured, the potential for injury was high. The accident occurred adjacent to Adelaide's operational metropolitan rail network with derailed vehicles causing significant damage to publicly accessible rail infrastructure such as pedestrian crossings, a passenger platform and a road level crossing. In addition, had metropolitan passenger trains been in the vicinity at the time of derailment, the risk of potential injury would have increased significantly.

The investigation determined that the most likely direct cause for the derailment of 7MP5 was significant wheel unloading as a wheel made contact with a check-rail at the entrance to the Belair crossing loop.

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[1] A platform in this context relates to the individual rail vehicles coupled via permanent drawbars which form a multi-unit rail wagon.

The investigation determined that a number of factors combined to contribute to this particular derailment. Any one factor in its own right is unlikely to have resulted in a derailment, but the four factors acting together greatly increased the likelihood of derailment.

- Wagon RQZY7066, with three empty platforms, was coupled immediately following the locomotives of 7MP5. Almost 2900 tonnes of trailing load was present behind the empty platforms, which exceeded the limit of 2600 tonnes stipulated by the Australian Code of Practice's marshalling requirements.
- The use of dynamic braking as the sole means of controlling train speed on the descending grade exerted significant longitudinal compressive forces on the RQZY wagon with three empty platforms coupled immediately behind the locomotives.
- In tare condition, the RQZY wagon is relatively light weight, rides on very stiff vertical suspension, and exceeds the maximum constant contact side-bearer (CCSB) pre-load recommended by the ACOP. It is likely that the very stiff vertical suspension reduces the ability of an empty RQZY wagon to absorb discrete wheel impacts, such as the interface with a check-rail.
- Track geometry influenced the oscillating motion of rollingstock, causing the right hand wheel flange into rail contact as the left hand wheel came into contact with the check-rail. It is likely that track irregularities only served to influence the timing of this movement, such that peak lateral forces occurred as the wheel came into contact with the check-rail.

Safety actions have already been implemented by Pacific National. A review was conducted, and a revised procedure for loading and marshalling issued in December 2004.

The ATSB makes a number of additional recommendations relating to:

- procedures for train loading, marshalling and handling
- functionality of software management tools
- review of rollingstock design and performance acceptance requirements
- review of civil infrastructure design and maintenance requirements
- review of documented standards
- implementation and monitoring of safety actions.

1 INTRODUCTION

At approximately 1006 on 21 November 2004, Pacific National freight train 7MP5 derailed in the Adelaide Hills near Glenalta. The freight train was travelling from Melbourne to Adelaide on the Defined Interstate Rail Network (DIRN) managed by the Australian Rail Track Corporation (ARTC). Immediately adjacent to the DIRN is Adelaide's broad gauge metropolitan passenger rail network owned and operated by TransAdelaide.

Train 7MP5 consisted of four locomotives leading 72 freight platforms and wagons. The total train length was 1474m, with approximately 2960 tonnes trailing the locomotives. A total of 10 platforms[2] and wagons were derailed, with five obstructing the TransAdelaide track and four coming to rest down an embankment in private residential properties.

Figure 1: View of TransAdelaide track and Glenalta Railway Station platform

Due to the magnitude of the derailment, damage to road and pedestrian crossings, a previous derailment in this area, and the proximity to TransAdelaide's passenger trains and to residential properties, the Australian Transport Safety Bureau (ATSB) initiated an independent investigation into the accident.

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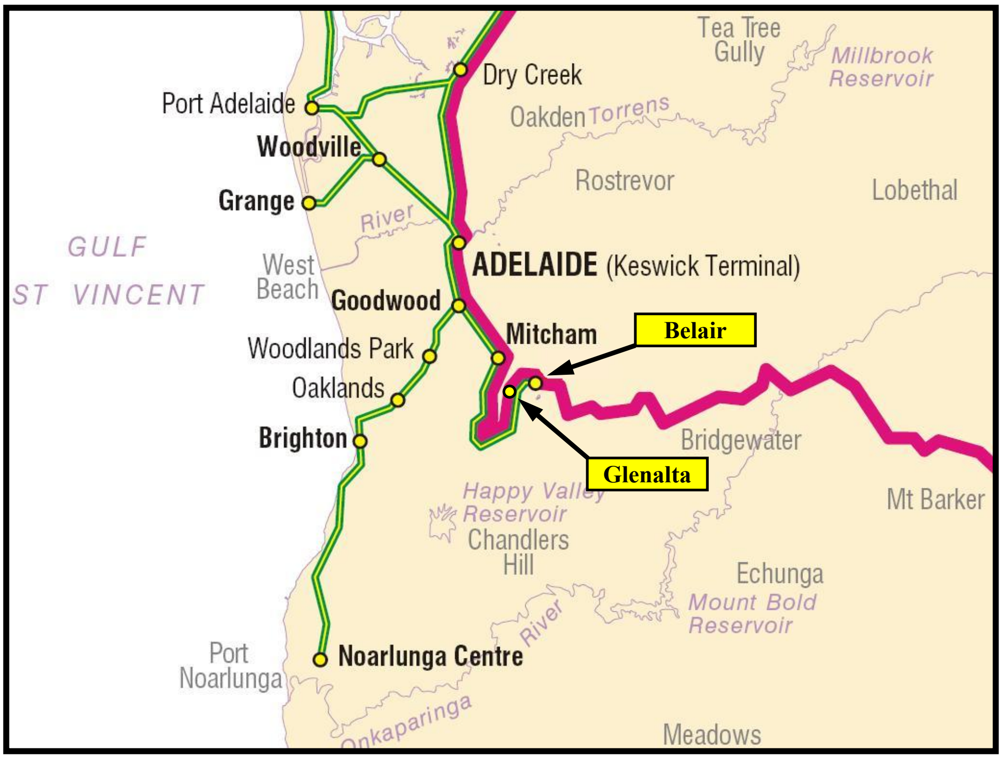
[2] A platform in this context relates to the individual rail vehicles coupled via permanent drawbars which form a multi-unit rail wagon.

2 OVERVIEW

2.1 Location

The derailment occurred over a 3.7km section of standard gauge track between Belair and Glenalta, located in the Adelaide Hills approximately 23 to 19 kilometres from Adelaide respectively. This section of track forms part of the DIRN's Melbourne to Adelaide rail corridor, and consists of continuously welded rail secured to concrete sleepers by resilient fasteners and supported on ballast. This configuration is typical of the standard used for the DIRN in South Australia.

Figure 2: Location of Belair, South Australia



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A standard gauge crossing loop is located at Belair. The crossing loop provides 1543m of standing room over a straight section of track with a slight down gradient. For approximately eight kilometres prior to the Belair crossing loop, the track exhibits a 1 in 45 down gradient, with a series of 190-350m radius curves. When travelling towards Adelaide, a 400m long, 240m radius left hand curve leads immediately into a right hand turn-out at the entry to the crossing loop.

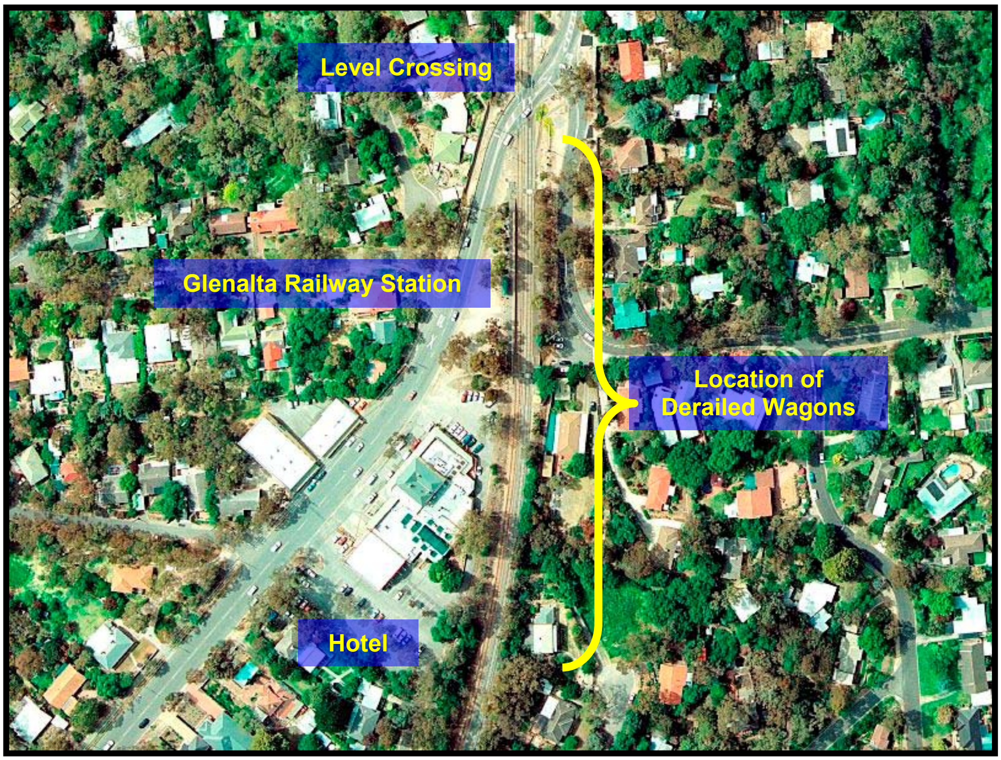
Immediately adjacent to the DIRN is TransAdelaide's broad gauge metropolitan passenger line. TransAdelaide's broad gauge rail network is primarily dedicated to the operation of Adelaide's metropolitan passenger train services and terminates near the Adelaide end of the Belair crossing loop.

A number of structures, consisting of station platforms, pedestrian crossings, overbridges and a road crossing, exist within the 3.7km section of track between Belair and Glenalta. While each of the railway stations are active for TransAdelaide passenger services, the platforms facing the standard gauge DIRN are unused.

The Belair railway station is located approximately 200m within the Adelaide end of the Belair crossing loop. The track continues with a 1 in 45 down gradient towards the Glenalta railway station through a series of 200-600m radius curves. The Pinera railway station is located about half distance between Belair railway station and Glenalta railway station. Each station has a pedestrian crossing located at one or both ends of the passenger platform, with the ‘Main Road’ level crossing located adjacent to the Glenalta railway station.

The majority of infrastructure damage occurred in the vicinity of the Glenalta railway station where derailed wagons came to rest in private residential properties and obstructed the TransAdelaide track. Figure 3 provides an aerial view of the derailment site and illustrates the proximity of residential properties and public areas such as the road level crossing, railway station and an adjacent hotel.

Figure 3: Aerial photograph of Glenalta, South Australia



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The ARTC network incorporates line-side signalling controlled remotely from a Centralised Train Control (CTC) centre in Adelaide, with voice communication between trains and train control achieved using UHF radio. The investigation determined that both signalling and communication systems had operated correctly and did not contribute either directly or indirectly to the derailment of 7MP5.

It is also recognised that, due to the freight line and passenger line running in close proximity to each other, a failure of the ARTC and TransAdelaide to effectively communicate could increase the risk of further damage or even injury. These issues are discussed in section 3.5 (Signalling and Communication).

2.2 Organisations

Australian Rail Track Corporation (ARTC)

The ARTC is the accredited rail organisation responsible for access to, and maintenance of, approximately 5860 route kilometres of standard gauge interstate track in South Australia, Victoria, Western Australia and New South Wales. This includes the section of DIRN between Melbourne and Adelaide over which 7MP5 was travelling.

Pacific National

Pacific National is the largest accredited, and privately owned, rail operator in Australia. Its primary business is transportation of rail freight; however, Pacific National also provides locomotives and crews to other organisations including passenger rail. Pacific National was the owner and operator of freight train 7MP5.

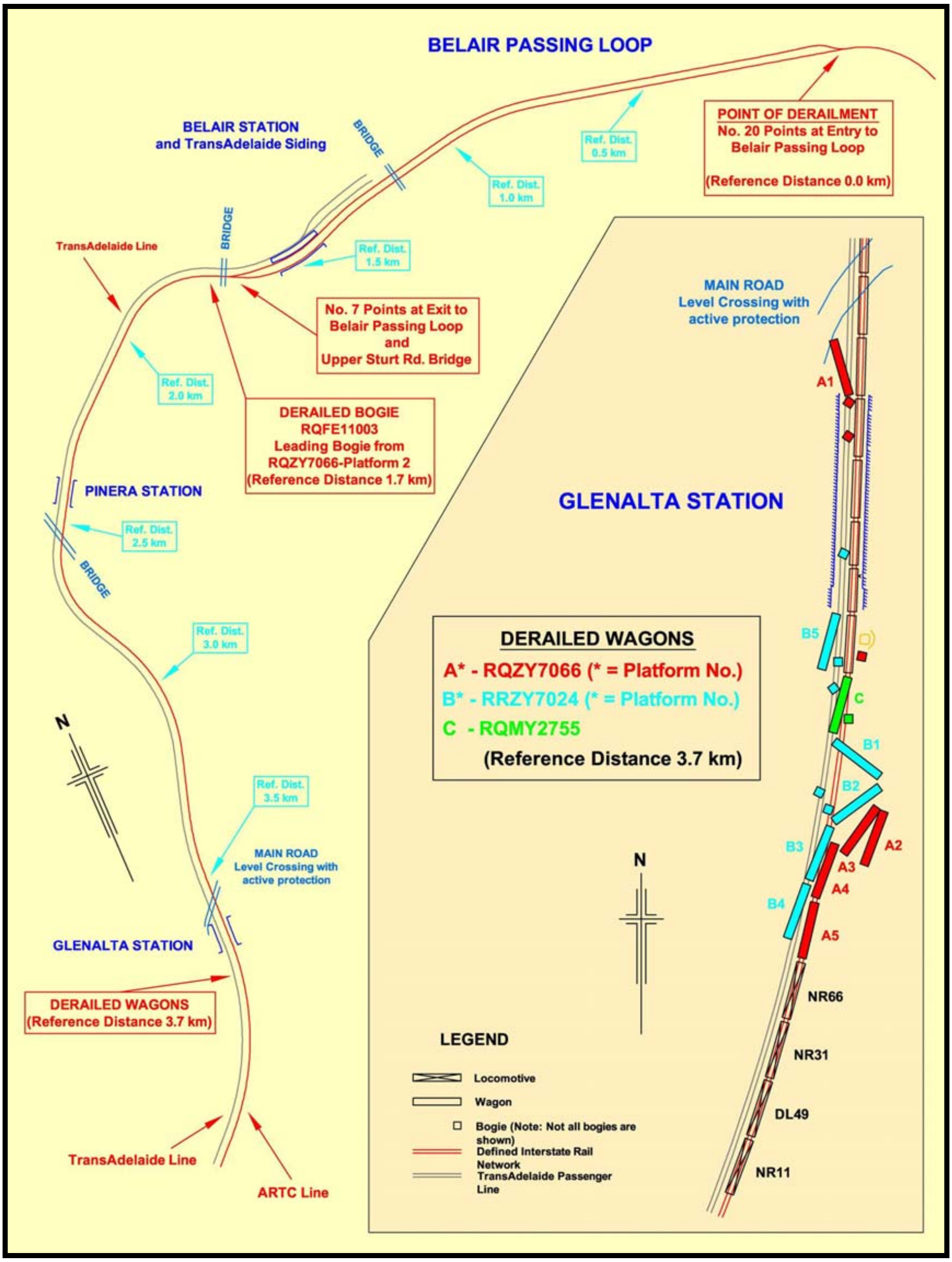
TransAdelaide

TransAdelaide is an accredited rail organisation providing public rail transport services to Adelaide’s metropolitan area. TransAdelaide is the owner, operator and manager of the passenger rail network which runs parallel to the ARTC network in the area where the derailment occurred.

2.3 The Occurrence

Freight train 7MP5 had negotiated a 400m long, 240m radius left hand curve that leads immediately into the turn-out at the entry to the Belair crossing loop. A right hand turn-out numbered as 20 points provides access to the crossing loop, however; the straight ahead main line route had been selected over the facing points. The locomotive data log verifies that 7MP5 was travelling at a constant 42 km/hr, well below the posted speed limit (50km/hr) for this section of track.

Figure 4: The derailment site



The point of derailment (0.0km)[3] occurred at the 'Vee' of the facing points, where markings indicated that a wheel had ridden over the check-rail allowing the opposite wheel to travel up the wrong side of the Vee.

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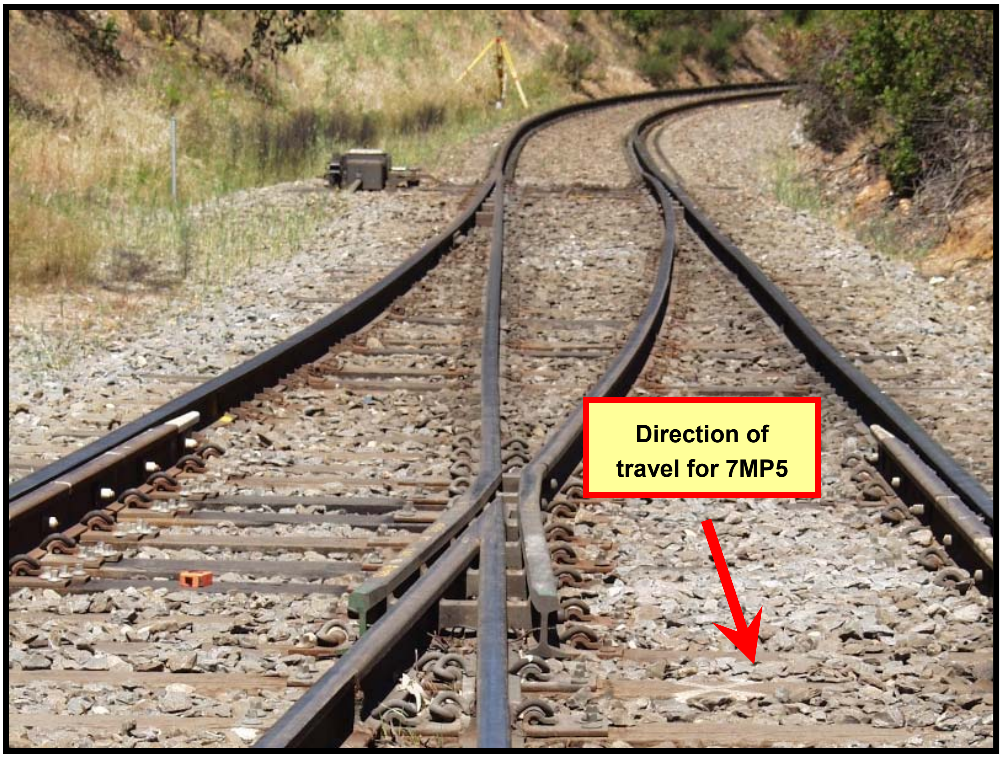
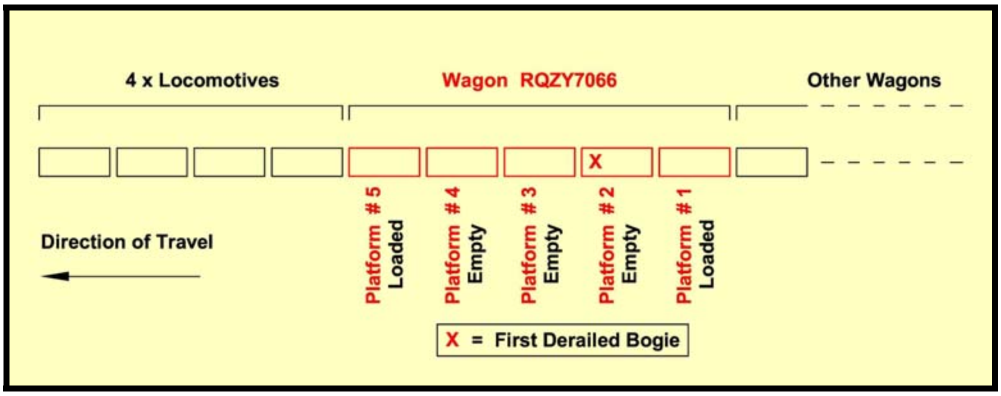
[3] Reference distances provided as kilometres from the point of derailment. Refer to Figure 3.

Figure 5: The turn-out at the entry to the Belair crossing loop



Wheel flange markings at point of derailment, damage to civil infrastructure and the post derailment location of wagon components suggest that initially only the lead bogie of the fourth platform (Platform #2 of 5-unit well wagon RQZY7066, coupled immediately behind the locomotives) derailed. The wheels from both axles continuing to strike the concrete sleepers on the right-hand side of each rail as the train progressed towards Glenalta. At the exit of the Belair crossing loop (1.7km) the leading derailed wheels struck the check-rail and Vee of the turn-out, resulting in the bogie lifting over to the left-hand side of the track and subsequently striking the point machine (number 7 points).

Figure 6: Train 7MP5, showing wagon RQZY7066 and the first bogie to derail



The bogie became detached from the platform, turned on an angle under the platform as it struck the concrete wall of a road bridge and was pushed out from under Platform #2 onto the left-hand ballast shoulder. Markings on the sleepers suggest a second bogie derailed to the right-hand side of the track at this point. Examination of the damaged rollingstock suggests that this was the trailing bogie of

Platform #2, most likely after striking the detached bogie resting on the ballast shoulder.

Examination also suggests that the following platform (Platform #1 of RQZY7066), being connected via a solid drawbar and having a relatively light load (8.8 tonnes), also lifted resulting in the displacement of the locating pin (king-pin) for its lead bogie. While it is probable that the bogie remained on track, the platform would have been unable to maintain its position in relation to the bogie. Platform #2, having no lead bogie and a rear bogie derailed to the right, would in turn have pulled the leading end of Platform #1 forward and to the right of its normal position on the bogie.

The train continued towards Pinera railway station (approximately 600m) where the derailed wheels struck the concrete panels of a pedestrian crossing. It is likely that it was this impact that caused the bogie to skew at an angle and slide, with a wheel and side bolster supported on a rail, the remaining distance to the Glenalta railway station (approximately 1.2km).

At Glenalta the sliding bogie, and possibly the leading edge of Platform #1, struck another concrete pedestrian crossing panel and the bitumen road edge of a level crossing. The downhill gradient (approx 1 in 45) accompanied by the loaded wagons pushing from behind caused Platform #1 and Platform #5 of the following 5-unit well wagon to lift in an inverted ‘V’ formation. The angle of the lifting wagons was sufficient to break the solid drawbars between their respective partner platforms, allowing the wagons to be pushed onto the adjacent TransAdelaide track.

Figure 7: View of RQZY7066 - Platform #1

Platform #1 of the first 5-unit wagon pivoted almost 180 degrees, demolished a pedestrian crossing, came to a rest against the Glenalta railway station platform and spilled its freight container onto the road. Platform #5 of the second 5-unit wagon, complete with its freight container, struck and slid the length of the station platform, demolished a second pedestrian crossing and came to rest on its side immediately after the station platform.

The impact at the level crossing alerted the locomotive drivers who immediately applied braking, finally stopping the locomotives and four platforms of the first 5-unit wagon approximately 200m beyond the Glenalta station. The brakes on the remaining wagons applied automatically due to loss of brake air pressure. However the gradient and momentum prevented the wagons from stopping before colliding (jack-knifing) with the wagons coupled immediately behind the locomotives. A total of 10 platforms and wagons were derailed, with five obstructing the TransAdelaide track and four coming to rest down an embankment into private residential properties.

2.4 Personnel Involved

The personnel involved at the time of derailment, and immediately following the derailment were:

- two Pacific National locomotive drivers crewing train 7MP5
- an ARTC train controller authorising the passage of the train towards Adelaide
- a TransAdelaide train controller preparing to manage the interface with the passenger network.

Consistent with Pacific National procedures, both drivers were requested to undertake a breath test following the accident. The tests, administered by an officer of the South Australia Police, returned a negative result for each driver.

The investigation determined that employee training, fatigue or medical factors did not contribute either directly or indirectly to the derailment of 7MP5. However, further analysis of individual actions was conducted to determine if there were any inconsistencies that may have contributed to the derailment of 7MP5. (Refer to section 3.0 Analysis)

2.5 Injuries

While no person was injured, the potential for injury was high.

The accident occurred in the vicinity of Adelaide’s operational metropolitan rail network with derailed vehicles causing significant damage to public accessible rail infrastructure such as pedestrian crossings, a passenger platform and a road level crossing. In addition, had metropolitan passenger trains been in the vicinity at the time of derailment, the risk of potential injury would have increased significantly. A further risk factor was the intrusion of rolling stock into residential properties.

2.6 Damage

Pacific National

A total of 10 individual rail vehicles were derailed, consisting of four platforms from the 5-unit well wagon numbered RQZY7066, all five platforms from the 5-unit well wagon numbered RRZY7024, and the container wagon numbered RQMY2755.

Of these, at least six individual rail vehicles and six bogies or components of bogies were expected to be beyond repair.

Australian Rail Track Corporation (ARTC)

Approximately 4km of standard gauge track was damaged, with concrete sleepers requiring the bulk of the repair and/or replacement. The point machine and control rods located at the Adelaide end of the crossing loop were extensively damaged and required replacing, as did the associated Vee crossing. Minor damage was caused to a road bridge abutment and signalling cable ducting. Pedestrian crossings were damaged at three metropolitan passenger stations.

Figure 8: Damaged point machine (left), concrete sleepers, bridge abutment and cable ducting (right)

A total of 23,585 minutes of delay to ARTC customers was recorded until normal services could be resumed on 23 November 2004.

TransAdelaide

Approximately 60 metres of TransAdelaide’s broad gauge passenger track was extensively damaged in the vicinity of the Glenalta railway station. Similarly, the passenger platform and lighting were damaged with two pedestrian crossings completely demolished. Derailed wagons also caused damage to line-side signalling, cabling and a standby power generation room. The damage sustained to a standby power generation room resulted in a minor diesel fuel spill which required clean-up using the appropriate control procedures.

On the day of the derailment three passenger services were cancelled and a further six delayed until substitute bus services could be organised. Buses continued to provide passenger services for the following four days, during which TransAdelaide’s broad gauge track was sufficiently repaired to allow train services to be reinstated on 25 November 2004.

2.7 Environmental Conditions

Information obtained from the Bureau of Meteorology (BoM) has established that at the time of the accident the weather in the vicinity of Belair was fine and clear. Following Adelaide's overnight temperature of 10.1 degrees[4], the day saw a maximum of 22.3 degrees with a recorded temperature at 0900 of 16 degrees. The day was relatively cloud-free with no discernible rainfall and only a light breeze.

The investigation determined that environmental factors were highly unlikely to have contributed either directly or indirectly to the derailment of 7MP5 on 21 November 2004.

2.8 Dangerous Goods

There was no release or spillage of dangerous/toxic goods of any kind from containers or wagon loads. While train 7MP5 was transporting dangerous goods on three wagons, these were located well back in the train consist and were not associated with the derailed wagons.

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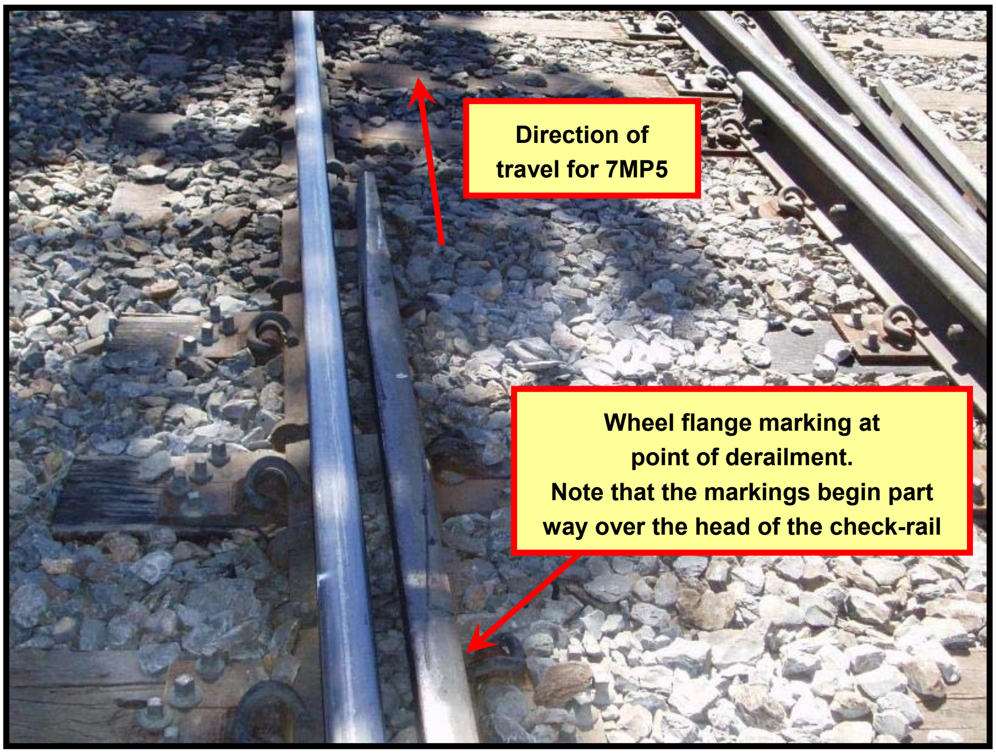
[4] Temperatures are shown in degrees Celsius.

3 ANALYSIS

The point of derailment occurred over a set of facing points that provide trains with access to the Belair crossing loop via a right hand turn-out. Freight train 7MP5 had negotiated a 400m long, 240m radius left hand curve that leads immediately into the turn-out which was set for the straight through main line.

Markings at the point of derailment indicated that a wheel had ridden over the check-rail allowing the opposite wheel to travel up the wrong side of the 'Vee'. The investigation noted the lack of a continuous mark over the entire width of the check-rail head. This indicates that the wheel was airborne prior to contact with the head of the check-rail.

Figure 9: Markings over check-rail at the point of derailment



Under normal operation, when a wheel set is traversing a set of facing points, the check-rail is positioned to guide the back of the flange of one wheel such that the opposite wheel flange face is clear of the crossing Vee. If the wheel is given the opportunity to travel the wrong side of the Vee, the wheel set is likely to derail.

The initial derailment of a single bogie occurred at the entrance to Belair crossing loop. The train continued on its journey, ultimately ending in a significant pile-up of derailed wagons and freight containers approximately 3.7km further towards Adelaide.

The main aim of the investigation was to identify the factors that contributed to the initial derailment. The events that occurred as a consequence were also analysed to identify any factors that may have increased the risk of further damage or injury.

3.1 Train Dynamics

To assist in the analysis, the ATSB engaged technical experts in dynamic simulation to analyse the dynamic response of rollingstock travelling over the point of derailment.

The Vampire[5] software package was used to assist in calculating the predicted dynamics of 7MP5 travelling over the point of derailment. Vampire is one of the world's leading rail vehicle simulation packages. As with most simulators, there is a level of assumption within both the software and the data used. Similarly, a level of simplification is often applied to input data with more refinements introduced as required, based on initial simulation results.

For example, as previously described, markings at the point of derailment imply that this was not a flange climb type derailment, but one where the wheel became airborne prior to contact with the head of the check-rail. If this is the case, wheel-rail contact geometry will not be as critical as the position of the wheel in relation to rail infrastructure. Two wheel profiles are common for RQZY wagons, ANZR-1 and WPR-2000. Considering that wheel-rail contact geometry was not a critical parameter, and that relevant wheels had not been re-profiled for some time, the lower performing ANZR-1 profile, running on new rail, was adopted for simulation.

Given these assumptions and simplifications within both input data and simulation software, the results should only be used as an indicator in conjunction with other analysis to draw an appropriate conclusion.

The rollingstock model within Vampire consisted of three vehicles, representing platform #3, #2 and #1 of RQZY7066, where the centre vehicle was the first to derail. The data used to develop the model were based on design and test information published for the RQZY class wagon. A load was added to the last vehicle to represent the 8.8tonne container load carried by platform #1, while platform #3 and #2 remained in tare condition.

The track geometry within Vampire consisted of the curve immediately prior to the turnout, the main line details of the turnout and a length of straight track beyond the turnout. The track information was based on design data, direct measured data and, where required, analysis of measured data.

The known dynamics of 7MP5 were obtained from the locomotive data log. To represent the compressive longitudinal load existing due to the dynamic braking of 7MP5, an equal and opposite longitudinal force was applied to the first and last wagon. Running the rollingstock model over the track model would then simulate the force components applied to the centre wagon as per the 'real' situation.

The Simulation

The aim of a simulation is to identify factors that may contribute to undesirable train dynamics. This was achieved by establishing a base reference using a simple model and then building in additional parameters to clearly understand their individual influences.

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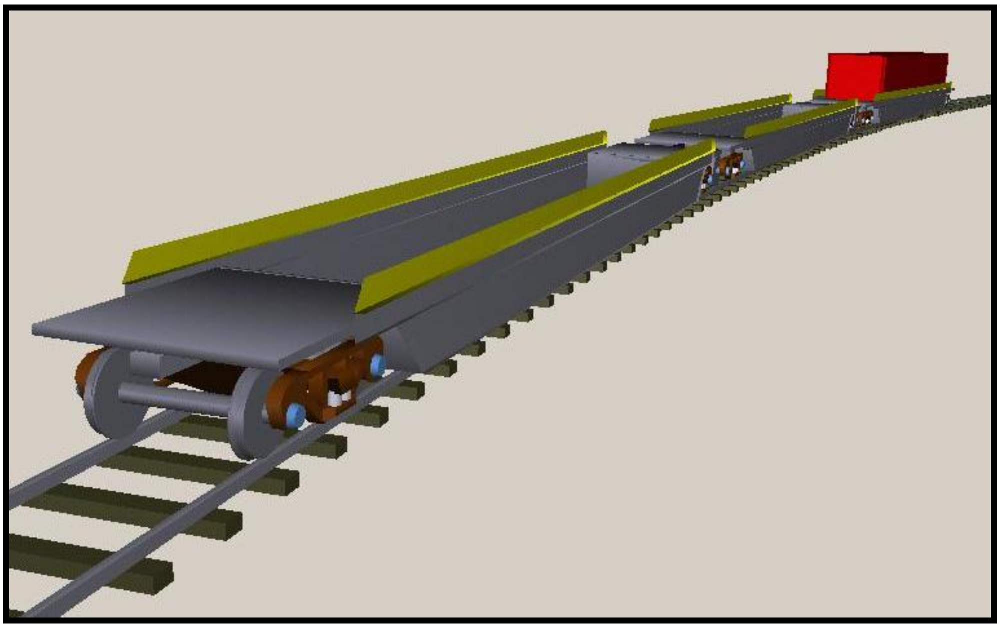
[5] 'Vampire' is a rail vehicle dynamics simulation package allowing the modelling of a virtual rail vehicle traversing measured track geometry.

Figure 10: Vampire representation of three RQZY platforms



For a base reference, Vampire simulated the three vehicles running through a slightly simplified version of the derailment site. In effect, the check-rail was removed from the track geometry such that the track model now consisted of a curve passing onto a straight section of track, while still incorporating the measured track geometry. With no longitudinal forces applied, the vehicles were seen to run through the curve with the leading outer wheel of each bogie in flange contact throughout the curved section of track. As they passed off the curved section and onto the straight, the wheel-sets oscillate from flange contact at one side of the track, to flange contact at the other side. The resulting maximum lateral force occurred as the wagon exited the curve, some 30m prior to the point of derailment. Vampire indicated that at no time did the lateral forces become sufficient to promote flange climb. Vampire also indicated that all wheels remained in contact with the rails throughout the simulation.

The next step was to add compressive longitudinal force consistent with the level of dynamic braking applied to train 7MP5. Under these conditions, the simulation indicated that wheel unloading increased slightly at some wheels, but the maximum value of wheel unloading was not affected. Even when increasing the longitudinal force by a further 50 per cent, Vampire still indicated that wheel-rail contact was maintained and lateral forces were not sufficient to promote flange climb. However, the simulation indicated that compressive longitudinal forces caused additional yaw rotation at the couplers, but not so much that the train became ‘buckled’ to a position where it could not recover. To identify how sensitive the RQZY wagon was to these compressive forces, a small lateral offset was applied in the couplers to promote buckling. The results indicated that any more than a small offset caused the lightweight vehicle body to lift off its centre plate. This demonstrated the sensitivity a lightweight RQZY vehicle body in tare condition had to the application of large compressive longitudinal forces.

So far, Vampire was unable to produce a result consistent with the actual derailment evidence. However, adding the check-rail to the model produced dramatically different results. With the compressive longitudinal force included, wheel unloading increased to more than 100%, indicating that at least two wheels became airborne. Interestingly, when no longitudinal forces were applied, Vampire still indicated 100% wheel unloading, albeit on different wheels and with different magnitudes. This indicated that an empty RQZY wagon at the rear of a train could also exhibit 100% wheel unloading. However, recognising that these wagons have been in use for close to 10 years, this result prompted a closer look at all parameters used within the Vampire model.

Further Simulation and Analysis

It became evident that wheel unloading was dependent on the right hand wheel being in flange contact as the left hand wheel came in contact with the check-rail. Since the wheel-sets oscillate from flange contact at one side to flange contact at the other side, it is logical that the maximum check-rail impact would occur when the peak oscillation to the right coincides with the left hand wheel making contact with the check-rail. Conversely, if peak oscillation occurs to the left, it is likely that minimal wheel unloading would be evident due to the left hand wheel's minimal impact with the check-rail.

Unfortunately, slight changes to various modelling parameters varied the frequency of oscillations, subsequently varying the likelihood of check-rail impact in the simulation. This demonstrated Vampire's sensitivity to minor model adjustments that ultimately prevented a conclusive outcome from the simulation process. However, sufficient information was obtainable to allow determination of the most likely contributing factors.

Considering Vampire's sensitivity to the track and rollingstock model required for this investigation, some verification was required to provide a level of confidence in the simulation results. This was achieved by substituting the rollingstock model with one commonly used as a 'sense check' for simulation purposes. The sense check model, referred to as a 'UK Mk3 Coach', is a passenger coach similar to an XPT[6] trailer car that is known to have a compliant suspension system and a high level of resistance to derailment.

The simulation using the Mk3 coach produced results consistent with what would be expected of this coach travelling through a curve and onto tangent track. This provided a level of confidence in Vampire's simulation results. However, what was interesting was how the coach reacted at the check-rail interface. It too exhibited wheel unloading when its right hand wheel was in flange contact and the left hand wheel came in contact with the check-rail. A series of simulations, conducted with various vehicle types and a track model that gave controlled check-rail contact, indicated that wheel lift at the check-rail interface was not an uncommon occurrence. However, in each case, the amount of wheel tread lift tended to be small (2mm or less). This level of lift would present minimal risk of derailment, since the flange is still engaged behind the working face of the check-rail. Discussions with the software developers of Vampire, and comparisons with manual calculations all confirmed that the simulation predictions were mathematically correct. This would imply that wheel unloading at the check-rail interface may be normal behaviour.

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[6] The XPT (Express Passenger Train) is a passenger train operated between Melbourne, Sydney and Brisbane.

If wheel lift at the check-rail interface was common behaviour, then a better measure of derailment risk is determining the magnitude of wheel lift, and what factors could influence the magnitude of lift. Further analysis indicated that any lateral component of longitudinal force due to rotation of the couplers could add to the lateral force at the flange back and increase the tendency for a wheel to become airborne.

Markings on the check-rail at the point of derailment indicated that a wheel may have become airborne, landing with the flange tip on top of the check-rail. To achieve this, a wheel would have to lift to a height greater than the flange height (31mm-32.5mm for bogie RQFE11003) and have a longitudinal flight of almost 1.5m. Vampire simulation was inconclusive in reproducing figures consistent with the site evidence. However, flight figures of 12.2mm height and 625mm length indicate that significant wheel lift and flight is possible given the appropriate dynamic configuration.

3.1.1 Summary of Train Dynamics

As it is recognised that dynamic simulation will usually rely on some level of assumption, both within the software and the data provided, the objective of Vampire simulation was to provide an indicator for further analysis. Despite Vampire's inability to provide a conclusive result, it did achieve the objective of providing an understanding of the dynamic events that were most likely to have occurred.

Dynamic simulation indicated that lateral forces were insufficient to promote simple flange climb. Evidence at the point of derailment would support the conclusion that this was not a flange climb derailment. The derailment markings were observed over the check-rail, which would require the back of a wheel to climb, not the flange face. Since the flange back and the check-rail working face are both near-vertical, flange climb would be very unlikely.

Dynamic simulation implied that a number of parameters are likely to influence wheel lift at the check-rail interface. The right hand wheel would need to be in flange contact as the left hand wheel came in contact with the check-rail. Rotational forces applied to the couplers are likely to add to the lateral force at the flange back and increase the tendency for a wheel to lift. Large compressive longitudinal forces are likely to influence these parameters. These parameters are likely to oscillate in frequency and magnitude, such that maximum wheel lift is likely to occur when the peak of each parameter coincides with the wheel's contact at the check-rail.

Dynamic simulation indicated that an empty RQZY wagon was very sensitive to large compressive longitudinal forces, such that small changes to drawbar angle promoted lift on the lightweight wagon body. It is possible that if 100% wheel unloading occurred, sufficient drawbar angle would result, which in conjunction with large compressive longitudinal forces could influence the magnitude of wheel lift and flight.

Dynamic simulation indicated that the most likely cause of derailment was sufficient wheel lift and flight, developed as the wheel came into contact with the check-rail. If sufficient lift occurred to allow the wheel's flange tip to land on top of the check-rail, the opportunity would exist for the opposite wheel to travel up the wrong side of the Vee and subsequently derail. Evidence at the point of derailment would support this scenario, as markings on the check-rail imply that the wheel was airborne prior to the flange tip's contact with the head of the check-rail.

Further analysis would be required in the following areas to determine factors that may have contributed to this scenario:

- Civil Infrastructure – The Vampire simulation was found to be highly sensitive to track geometry. The fact that slight changes in track geometry caused changes to the flange contact oscillations was considered normal. However, conformance against design and maintenance standards was assessed to identify any element or defect that may have contributed to wheel impact with the check-rail. (Refer to section 3.2)
- Rollingstock – Again, the Vampire simulation was found to be highly sensitive to rollingstock parameters. This was evident when large compressive longitudinal forces were applied to the relatively light weight RQZY body in tare condition. Also of significant interest was Vampire's result of 100% wheel unloading of a tare RQZY wagon without the compressive forces. (Refer to section 3.3)
- Train Loading and Marshalling – Increasing the wagon load results in a greater wheel load, subsequently reducing the likelihood of a wheel lifting from rail contact. Also, as a wagon is marshalled closer to the front of a train, the longitudinal compressive forces exerted on that wagon increase. Vampire indicated that these factors were critical to the simulation results. (Refer to section 3.4.1)
- Train Handling – Train handling technique can contribute to high longitudinal compressive forces within a train, especially when utilising dynamic braking on steep descending grades. Vampire indicated that the simulation was highly sensitive to compressive longitudinal forces. (Refer to section 3.4.2)

3.2 Civil Infrastructure

The Vampire simulation identified that wheel impact with the check-rail was a key factor in the derailment of 7MP5. There are two primary areas relating to civil infrastructure that could contribute to this impact. One is the configuration of the check-rail and the rail immediately preceding the leading edge of the check-rail. The other is the overall geometry through the curve and the turnout. While it may be normal for a wagon to oscillate between flange contact on one rail to flange contact on the other, track geometry can dictate the magnitude of these oscillations and subsequently the forces existing at the wheel-rail interface.

As the point of derailment occurred over the Vee of the turn-out at the entry to the Belair crossing loop, the track analysis is focused predominately on this turn-out and the left hand curve leading immediately into the turn-out. The turn-out is positioned with the tip of the switch blade within a few metres of the tangent point of the curve. It is relevant and beneficial to understand a little of the history behind the positioning of this turn-out, since analysis identified geometry that was slightly unconventional in some aspects.

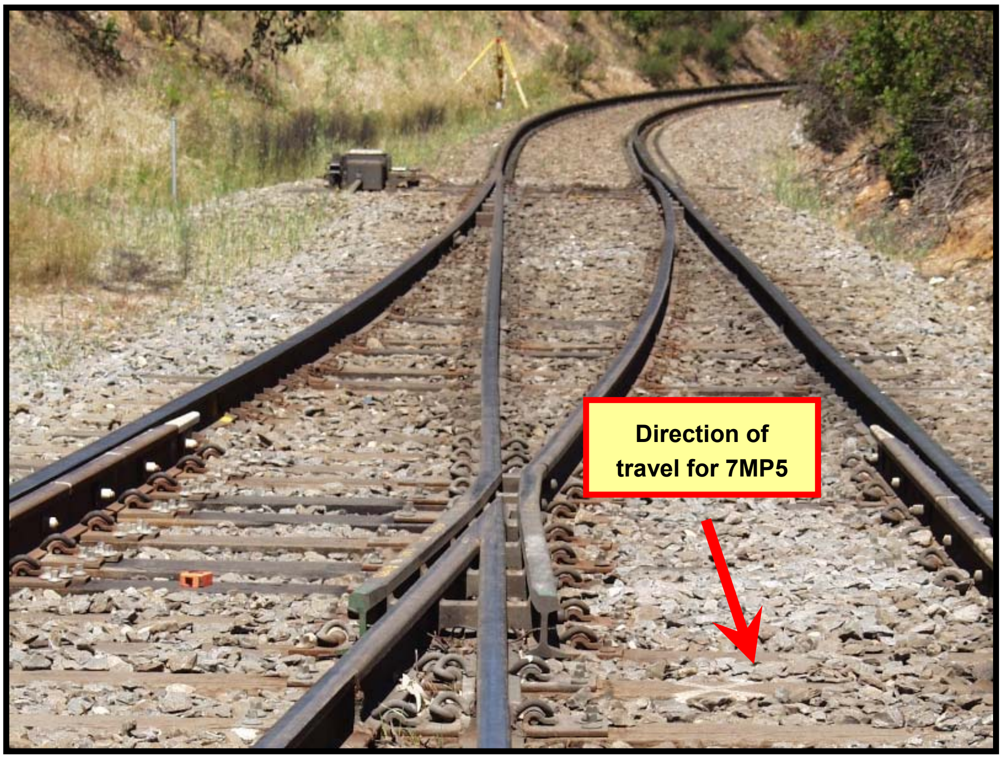
Prior to 1995, the Adelaide to Melbourne railway line was 1600mm (Broad) gauge. The section from Adelaide to Belair was configured for the operation of both metropolitan passenger trains and freight trains over the same broad gauge double track. As Belair was a termination station for the metropolitan passenger trains, a crossover was provided to allow access to the station platform and subsequent access to the return track to Adelaide. The double track continued beyond the station platform before merging into a single bi-directional broad gauge track.

Melbourne bound freight trains were regularly held at Belair pending the arrival and crossing of an Adelaide bound train. However, as the length of the interstate freight trains continued to increase, the rear end of long Melbourne bound freight trains would foul the crossover at the Adelaide end. Metropolitan passenger trains would consequently encounter considerable delays until the freight train crossing movement was completed.

To overcome this problem, the double track beyond Belair was extended to the 23 km post. In addition, the double track was signalled for bi-directional working, effectively becoming a main line and crossing loop of approximately 1466m.

In 1995, the section between Adelaide and Belair was segregated, allowing the metropolitan passenger trains and interstate freight trains to operate over their own dedicated bi-directional, single-tracked railway lines. The track was also upgraded, allowing the continuously-welded rail to be secured to ballasted concrete sleepers with resilient fasteners. This configuration is typical of the standard used for the DIRN in South Australia. At the same time, the entire Adelaide to Melbourne railway line, including the Belair crossing loop, was converted to 1435mm (Standard) gauge.

Figure 11: View of the curve leading immediately into the Belair turn-out



With the ever-increasing length of freight trains, the Belair standard gauge crossing loop was lengthened in, or about, the year 2000, increasing the 1466.3m standing room to 1500m. The turn-out was relocated closer to the adjacent curve. It is evident that this resulted in the turn-out (tip of the blade) being located only 3m from the tangent point of the curve. Similarly, it is evident that the transition curve was removed and the cant run out entirely within the curve.

3.2.1 Analysis of Civil Infrastructure

For analysis, data were sourced from published ARTC documents, and actual data measured immediately following the derailment.

Table 1: Published curve details[7]

Design Element	Design Value
First tangent point [in direction of travel]	23.420 km from Adelaide
Last tangent point [in direction of travel]	23.044 km from Adelaide
Radius	nominally 240 m
Cant (super-elevation)	listed as 80 mm
Transition (Mt Lofty end)	listed as 40 m
Transition (Belair end)	listed as Nil
Permissible max speed	50 km/hr

At the time of derailment, the standards and procedures for design, inspection and maintenance of civil infrastructure in South Australia were documented within the ARTC contract with its maintenance provider. However, the ARTC advised that their future intention was to adopt the standards and procedures documented in the Australian Code of Practice (ACOP). The civil infrastructure through the derailment location was analysed and conformance verified against the ARTC documented standards and procedures. For comparison, conformance against the ACOP was also checked with any differences identified. The ATSB engaged a civil engineer, with specialist expertise in track infrastructure design, to provide assistance with this analysis.

Inspection of civil infrastructure indicated that the track structure through the curve and the turn-out was generally in good condition. The ballast was clean and the drainage adequate.

Horizontal Alignment and Transitions

Horizontal alignment is expressed in terms of tangent (straight) track and curves of a specified radius. To avoid instability due to sudden changes of direction at tighter curves (low radius), a transition is generally provided whereby the radius gradually decreases from the tangent point (large radius) to the designed curve radius (low radius).

When considering the horizontal alignment in isolation, there does not appear to be any breaches of the ARTC standards or the ACOP. However the actual alignment is slightly unconventional in some aspects.

Through analysis it is evident that over the last 40m before the points, the 240m radius curve has been tightened to 190m radius. This is consistent with the historical practice of sharpening the curve over the last 40m and then superimposing a transition curve. In this case, when the turn-out was placed at the tangent point of the curve, the curve radius has been returned to 190m by removing

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[7] ARTC - Network Interface Co-ordination Plan, Document No. TA02, Issue 2.1, 30 June 2003

the transition. However, the further step of restoring a 240m radius throughout the curve has not been done. Consequently, the cant has been run out over the last 53m of the curve.

It would also appear that the straight leg of the turn-out has been skewed to meet the tangent point of the tightened 190m radius curve. If the last 40m of the curve had been redesigned to a radius greater than 190m, it is likely that the tangent point could have been located in line with the straight leg of the turn-out.

Both the ARTC standards and the ACOP allow for curves without transitions by the use of 'virtual transitions', in which the cant is run out from the full cant to zero over a length equivalent to a transition. Normally, this cant would be reduced from full cant to zero, half on the curve and half on the straight; but in this case, because of the proximity of the tangent point to the turn-out, all the cant is run out on the curve. However, under such circumstances, the speed of trains should comply with the rules for cant deficiency.

Superelevation and Cant Deficiency

As a vehicle traverses a curve, the vehicle is subjected to overturning forces, and the track subjected to increased lateral forces. While it is unlikely that a wagon will overturn under normal operating conditions, the overturning force has the effect of transferring vertical forces from the wagon's inner side-bearer to the outer side-bearer, resulting in a corresponding transfer in wheel loading. To limit the overturning forces on a vehicle, superelevation or cant is applied whereby the outer rail is raised to a higher level than the inner rail. The magnitude of the overturning force is dependent on the radius of the curve, the amount of cant, and the speed of the vehicle. For design and analysis, the equilibrium cant is calculated using the curve's design radius and design speed. In reality, the actual cant is generally below this value with the difference known as the cant deficiency.

As previously described, the curve differs slightly from the published design parameters. The 'actual design' consists of two sections, one having a radius of 240m and the other a radius of 190m. Consequently, calculations and verification of conformance against standards should be conducted with consideration to the two sections.

Table 2: 'Actual design' parameter

Parameter	Value	Value
Radius	240 m	190 m
Design cant	80 mm	80 mm
Permissible max speed	50 km/hr	50 km/hr
Equilibrium cant	123 mm	156 mm
Cant deficiency	43 mm	76 mm

From a design perspective, the ARTC standards and the ACOP specify typical design criteria limiting the maximum permissible cant to 150mm and the cant deficiency to 80mm. However, from an inspection and assessment perspective, the ARTC standard specifies the maximum cant deficiency as 75mm. When considering the actual design parameters over the 190m radius section, the calculated cant deficiency is 76mm. A cant deficiency parameter close to the specified limit provides early indication that the permissible maximum speed may be too high over the 190m radius curve. In practice, actual cant in service generally measures below the design cant, reinforcing this indication.

From an inspection and maintenance perspective, the ARTC standards allow for a variation in cant (or cant deficiency) of 42mm before a response is required to monitor and rectify the defect (the ACOP variation limit is 49mm). Therefore, cant deficiency may increase to 85mm on the 240m radius section and 118mm on the 190m radius section. For the 240m radius section, the actual cant varies between 59mm and 71mm (Refer to Appendix 7.1) resulting in a cant deficiency as high as 64mm (based on an equilibrium cant of 123mm). This is within the limits permitted by both standards.

However, this is not the case where the curve radius is reduced to 190m. On this part of the curve, the actual cant varies between 25mm and 48mm (Refer to Appendix 7.1) resulting in a cant deficiency as high as 131mm (based on an equilibrium cant of 156mm). This exceeds the limits specified in both standards. There are two reasons why cant and cant deficiency may not conform to the requirements of the ARTC standard and the ACOP. Either the required cant has not been maintained, or the design parameters are not entirely appropriate.

Looking purely from the perspective of maintaining a 190m radius curve with a design cant of 80mm, a cant of 25mm equates to a cant variation of 55mm. Consequently, this defect requires a P2 response (inspect within 7 days and repaired within 28 days) in accordance with the ARTC standard[8]. This standard also requires that a speed restriction (calculated at 40 km/hr) be applied until the defect is repaired.

However, when considering the curve from a design perspective, the ‘actual design’ has a radius of 190m with the cant reducing to zero at the tangent point. From this information, it is possible to calculate the maximum permissible speed based on the requirements of the ARTC standards. Since actual cant reduces to zero and the maximum permissible cant deficiency is 75mm, then the equilibrium cant should not exceed 75mm. For a standard gauge curve with a design radius of 190m and cant reducing to zero at the tangent point, the calculated maximum permissible track speed is 35km/hr. While the ACOP specifies a higher limit for cant deficiency at 80mm, the calculated maximum permissible track speed is again 35km/hr.

It should also to be noted that measurements indicate a 25mm cant at the tip of the turn-out blade, in other words a departure from design vertical alignment or “top”. While this measurement is within both the ARTC and ACOP standards, it would likely have contributed to the oscillating motion of rail vehicles.

Superelevation Ramp Rate

Similar to horizontal alignment, sudden changes in vertical alignment (superelevation) can also affect vehicle stability. Therefore, superelevation is only gradually transitioned from zero on tangent track to designed cant in the curve.

Both design and actual figures for superelevation ramp rate are within the permissible limits documented in both standards.

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[8] Track Geometry – Inspection and Assessment, Issue 2.3, May 1998

Rate of Change of Cant or Cant Deficiency

Both design and actual figures for rate of change of cant or cant deficiency are within the permissible limits documented in both standards except for a 5m section 20m prior to the turn-out. At this point the cant deficiency reduces by 61mm resulting in a 170mm/sec rate of change.

The ARTC standards prescribe the maximum permissible rate of change of cant or cant deficiency as 55mm/sec (the ACOP rate of change limit is 65mm/sec). This non-compliance against both standards is due to imperfections in the top as well as the excessive curve speed as previously described.

Gauge, Twist and Top

The parameters for gauge, twist and top were generally within the limits permitted by the ARTC standards and the ACOP. However, in one instance a wide gauge measurement of 25mm was recorded.

When assessed against the ARTC standards, a measurement of 25mm requires a maintenance response of monitoring and consideration of planned maintenance to rectify the defect. When considering the ACOP, a maximum wide gauge measurement of 26mm is permitted before a maintenance response is required.

When assessed against the relevant maintenance standards at the time of derailment, a non-compliant gauge measurement was identified. However, this defect occurred in the curve, some 200m prior to the point of derailment, and was not considered a contributing factor to the derailment of 7MP5.

Turn-out Details

The point of derailment occurred at the Vee of the facing points, where markings indicated that a wheel had ridden over the check-rail allowing the opposite wheel to travel up the wrong side of the Vee. The Vampire simulation, while not conclusive, indicated that the most likely cause of derailment was significant wheel lift and flight as the wheel came into contact with the check-rail. The turn-out geometry associated with these scenarios is the area defined as the ‘crossing area’, and the track section immediately prior to the check-rail.

The geometry dimension that would increase the likelihood of a wheel impact with the check-rail is wide gauge. Careful control of gauge at the entry to a check-rail serves to guide a wheel into the check-rail gap, reducing the likely magnitude of any impact force between the wheel flange back and the check-rail. The ARTC standards specify a wide gauge limit of 24mm, beyond which a maintenance response is required. (the ACOP wide gauge limit is 26mm). The maximum gauge measured through the main line route of the turn-out is 14mm, well within the prescribed limits of both standards. The section immediately prior to the check-rail only exhibits a wide gauge of 4mm. While it is recognised that variations in gauge can contribute to the oscillation of a wagon from flange contact on one rail to flange contact on the other, this is considered normal. In fact, check-rails are designed to allow for both wagon oscillation and wide gauge (within limits) by incorporating a flared end to guide a wheel through the flange gap. All flares on check-rails were examined and found to be 80mm in accordance with the ARTC standards and the ACOP.

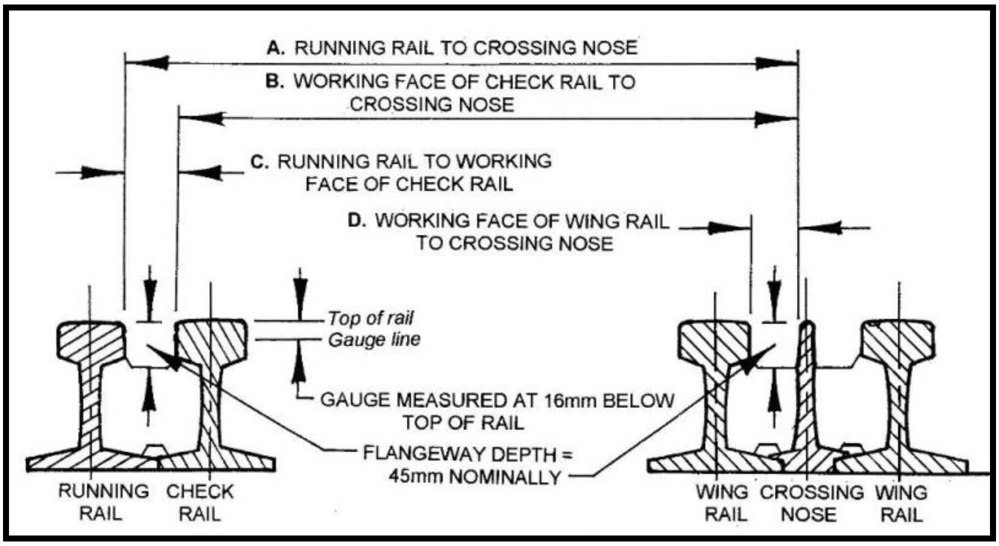
For maintenance inspection and assessment, the ARTC standards specify dimensional limits for the ‘crossing area’ bounded by the check-rails and the Vee. Similar dimensional limits are documented in the ACOP. The following turn-out measurements were taken at the V-crossing and compared to the criteria documented in each standard.

Table 3: Turn-out measurements (Refer to Figure 12)

Parameter	**Design Dimension**	**Actual Dimension**	**Tolerance**	
			ARTC Standard	**ACOP**
A	1435mm	1435mm	-0mm	- 4mm
B	1390mm	1391mm	-1mm	-1mm
C	45mm	43mm	-5mm, +3mm	±1mm
D	45mm	44mm	-5mm, +3mm	±1mm

While assessment against the ARTC standards shows each measurement as compliant, assessment against the ACOP shows non-compliance for dimension C (Refer to Table 3 and Figure 12). This dimension is not considered critical since the flared check-rail entrance will guide the wheel into the flange-way and the tight flange-way will eventually wear to the design dimension. However, a tight flange-way can serve to increase the contact forces between the wheel flange and the check-rail. The critical measurement is B – D (1347mm), which must be less than the back-to-back dimension of the rollingstock wheels (1357mm to 1360mm) and is compliant.

Figure 12: Turn-out cross-section at V-crossing (Refer to Table 3)



3.2.2 Summary of Civil Infrastructure

The analysis indicates the civil infrastructure complies with the ARTC standards and the ACOP in most respects. However, some cases of non-compliance or borderline compliance exist.

- A wide gauge measurement of 25mm was non-compliant against the ARTC maintenance standards. The standard allows gauge widening up to 24mm before a maintenance response is required. This defect occurred in the curve, some

200m prior to the point of derailment, and was not considered a contributing factor to the derailment of 7MP5.

- The actual curve consists of a nominal radius of 240m sharpening to 190m prior to the tangent point. It is non-transitioned with all the cant runout within the curve. Through calculation, this configuration indicates the maximum speed should not exceed 35 km/hr; however, the published curve speed is 50km/hr.
- A section of the curve, approximately 20m from the tangent point, exhibits an excessive rate of change of cant deficiency which does not comply with the ARTC standards or the ACOP.
- A 25mm cant at the tip of the turn-out blade was measured. While this measurement is within both the ARTC and the ACOP standards, it would likely have contributed to the oscillating motion of rail vehicles.

3.3 Rollingstock

Train

Pacific National train 7MP5 originated at the Melbourne Freight Terminal and was travelling to Perth via Adelaide. The train consisted of three NR class and one DL class diesel electric locomotives, followed by 72 platforms and wagons. The total train length was 1474m, with approximately 2960 tonnes trailing the locomotives.

Immediately following the locomotives, were two 5-unit well wagons identified as RQZY7066 and RRZY7024 respectively. The analysis focussed predominately on wagon RQZY7066, as the evidence suggested a bogie from this wagon was the first to derail.

Wagon RQZY7066

The RQZY class wagon is a 5-unit well wagon. This style of wagon consists of five individual wagons referred to as ‘platforms 1 to 5’, coupled by rigid drawbars. The platforms are a low-floor design to allow double stacking of freight containers.

Table 4: Documented details for Pacific National RQZY class wagon

Element	Value
Tare Weight:	98 tonnes
Length:	106.5 metres
Max Gross Weight:	420 tonnes
Capacity:	322 tonnes
Max Allowable Speed:	115 km/h @ 320 tonnes
	110 km/h @ 420 tonnes
Number in Class:	28 wagons
Date First Built:	1995

Figure 13: Pacific National RQZY class wagon[9] (Note RRZY wagon is similar)

Wagon RRZY7024

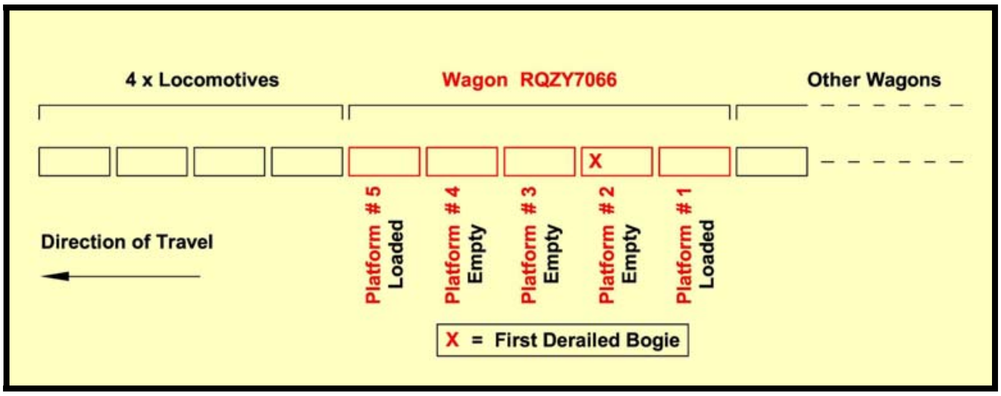
The RRZY class wagon is a strengthened version of the RQZY wagon and identical in configuration. The wagon details are also identical except that due to strengthening, the tare weight is four tonnes higher (102 tonnes), resulting in a slightly lower allowable payload capacity (318 tonnes).

3.3.1 Static Analysis of Rollingstock

The ATSB engaged a mechanical engineer, with specialist expertise in rollingstock design and maintenance, to provide analysis of the derailed wagons to determine whether the rollingstock was fit for purpose on the day of the accident.

Wagon number RQZY7066, a 5-unit well wagon, was coupled immediately behind the locomotives with Platform #5 leading. Platform #5 was loaded with a 26.5 tonne container giving a gross platform weight of 46.1 tonnes. Platform #1 was loaded with an 8.85 tonne container giving a gross platform weight of 28.45 tonnes. The remaining three platforms were unladen, giving a gross platform weight of 19.6 tonnes each.

Figure 14: Train 7MP5, showing RQZY7066 and the first bogie to derail



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[9] Photo and details sourced from Pacific National's Wagon Details Manual, Document WDM-RQZY-02, dated 21 February 2003

Wheel flange markings at point of derailment, damage to civil infrastructure and the post derailment location of wagon components suggests that the leading bogie (number RQFE-11003) of the fourth platform in the train consist (Platform #2 of RQZY7066, as per Figure 14 above) was the first bogie to derail. As the investigation progressed, analysis determined that the mechanism of derailment related primarily to the platform initially derailed (Platform #2) and the adjoining two platforms (Platform # 3, leading and Platform # 1 trailing).

The bogies on RQZY7066 were a Super Service Ride Control type manufactured by Bradken. Wheel-set measurements and friction wedge heights were within permissible limits, as was the condition of the centre plate bowls. Rub marks were evident on the trailing axle of the lead bogie of Platform #1 (RQFE-18642), with the top of one wheel flange worn to a wide flat. Corresponding heavy rub marks on the wagon structure suggest that this bogie may have been displaced both laterally and longitudinally during the derailment.

During the investigation it was noted that the condition of two wheel-sets, each in different bogies (RQFE-18641, trailing bogie of Platform #1 and RQFE-18622, leading bogie of Platform #3) was less than optimal. Both these sets had one wheel flange close to the thickness limit with a much fuller flange on the other wheel. As this effect occurred on only one wheel-set in each bogie, it is unlikely to be due to bogie lozenging or crabbing. The most likely cause is a slight misalignment of the wheel-set in the frame or of the wheels on the axle. However, further analysis indicated that this wheel condition was not a contributing factor to the derailment.

Traditionally, wheel profiles were one of the first items addressed during any train or vehicle examination or inspection, either in traffic or at maintenance facilities. It is recognised that organisational pressures have, over time, resulted in changes to traditional practices, and examination of wheel condition at arrival and pre-departure inspections may have suffered this fate.

However, it should be noted that if an organisation relies on periodic maintenance to address wheel condition, it is possible that a wheel-set or other component approaching the condemned limit could be permitted to return to operational service. In the case of a misaligned wheel-set, accelerated wear may result in the component exceeding its permissible limit before the next scheduled service. It is essential that the known risks of potentially serious faults that could lead to catastrophic wheel failure, such as thermal cracks in wheels, continue to be proactively managed.

3.3.2 Dynamic Analysis of Rollingstock

As described in section 3.1 Train Dynamics, the Vampire simulation software was used to analyse the dynamic response of rollingstock travelling over the point of derailment.

This analysis identified a few unusual parameters in relation to the design of the RQZY wagons. In tare condition, the RQZY wagon is relatively light weight; however, it rides on very stiff vertical suspension. In addition, approximately 97% of the tare body weight is supported on the constant contact side-bearers (CCSB). The ACOP[10] specifies that the maximum CCSB pre-load is not to exceed 85% of

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[10] Volume 5, ‘Rollingstock’, Part 2, ‘Common Requirements’

the tare body mass. Generally, this configuration would produce poor results when tested for response to track twist. However, the ability of the RQZY to pass the relevant twist tests is reliant on its torsionally very flexible body in tare condition.

A factor not addressed within the testing procedures for static response to track twist is the performance of a lightly-loaded vehicle. While the RQZY wagon exhibits a torsionally flexible body in tare condition, when loaded the freight container itself would contribute to structural stiffness resulting in a substantially stiffer platform. Under these conditions the RQZY's performance over twisted track becomes more reliant on the bogie suspension. However, the RQZY bogie suspension is very stiff and only operates effectively when supporting substantial weight. It is likely that if the loaded freight container were empty, the RQZY's performance over twisted track would deteriorate significantly. It would appear that tare and maximum load requirements are considered in the RQZY wagon design; however, their design may not fully accommodate performance criteria when carrying an empty or very lightly loaded container.

Vehicle suspension aims to control the wheel-sets so as to maintain wheel-rail contact. This includes negotiation of track twists and absorbing the forces exerted on a wheel due to discrete wheel impacts. For example, the RQZY wagon in tare condition may be able to handle track variations such as twisted track, because of its torsionally flexible body in tare condition. However, the wagon will rely on its suspension components to absorb discrete wheel impacts such as the interface with the check-rail.

As described in section 3.1 (Train Dynamics), Vampire indicated 100% wheel unloading on the RQZY wagon when no longitudinal forces were applied. This would imply that an empty RQZY wagon, marshalled to the rear of a train could also exhibit 100% wheel unloading. Very stiff vertical suspension on the light weight RQZY wagon, and the inability of that suspension to absorb discrete wheel impacts, goes some way to explaining this result. Further analysis focused on the flight characteristics following wheel lift, and indicated that application of the longitudinal forces could affect how high the wheel would lift off the rail. It is likely that if an empty RQZY wagon marshalled to the rear of a train exhibited 100% wheel unloading, the flight characteristics may only be minor. Progressing this scenario further, it is possible that 100% wheel unloading on an empty RQZY wagon may not be an uncommon occurrence, albeit minor with no detrimental outcomes. These wagons have been in use for close to 10 years. However, it should also be recognised that even if 100% wheel unloading is occurring, it is unlikely to occur at all times, since there are many other parameters that dictate the position of the wheel as it passes through a check-rail.

When compared with the modelled behaviour of the 'Mk3 Coach', the RQZY wagon showed greater tendency towards wheel lift at the check-rail interface. Vampire simulation indicated that the parameter most likely responsible for the Mk3's better performance at the check-rail interface is its softer suspension coupled with slightly heavier axle load.

The number and rating of suspension springs is dependent on the maximum load carried by a rail vehicle. However, the weight difference between a tare freight vehicle and a fully loaded freight vehicle can be considerable. If all springs are active from tare to max load, the vehicle will be very stiff when in its tare condition. This is the case for the RQZY wagon, where all springs are active irrespective of the load carried. For the RQZY wagon, the load on each bogie can vary between approximately 5 tonne (half body mass) and 37 tonne (at max load). Even at its maximum load, it is possible that the vertical spring stiffness of the RQZY wagon may be high.

It is not uncommon for bogie suspension to incorporate springs that become active in two stages. When designed in this way, only some of the springs are active when the wagon is in its tare state, with the second stage springs only becoming active as extra weight is added to the wagon. A suspension design that is more suited to variable loads may improve the resistance to wheel unloading for RQZY and similar wagons.

3.3.3 Summary of Rollingstock

While there was considerable damage to the wagon structures and bogies due to the derailment and recovery activities, there was no indication of any fault, defect or deficiency on the day of the accident that would indicate the rollingstock was not fit for purpose as designed.

However, some unusual configurations or wear were observed:

- Two wheel-sets, unrelated to the first derailed bogie, had one wheel flange close to the thickness limit with a much fuller flange on the other wheel. As this effect occurred on only one wheel-set in each bogie, it is unlikely to be due to bogie lozenging or crabbing. The most likely cause is a slight misalignment of the wheel-set in the frame or of the wheels on the axle.
- In tare condition, the RQZY wagon is relatively light weight, rides on very stiff vertical suspension, and exceeds the maximum CCSB pre-load recommended by the ACOP. The RQZY wagon is reliant on its torsionally flexible body in tare condition to pass the relevant twist tests. It is likely that carriage of empty containers may compromise this torsional flexibility without providing sufficient load to enable the stiff suspension to become effective.
- It is likely that the very stiff vertical suspension reduces the ability of an empty RQZY wagon to absorb discrete wheel impacts, such as the interface with a check-rail. This may allow for 100% wheel unloading under some conditions.

Figure 15: The first bogie to derail (left), approximately 2km prior to the final location of derailed wagons (right)

3.4 Procedures

As described in section 3.1 (Train Dynamics) the Vampire simulation software was used to analyse the dynamic response of rollingstock travelling over the point of derailment. Vampire identified large longitudinal compressive forces, exerted on an empty RQZY wagon, as a potential contributor to the derailment of 7MP5. There are three primary areas governed by documented procedures and standards that guide the management of these factors:

- Train Loading – Managing the load placed on a wagon.
- Train Marshalling – Managing where a load is placed in relation to the train consist.
- Train Handling – Managing how a train traverses a section of track.

As a wagon is marshalled closer to the front of a train, the longitudinal compressive forces that may be exerted on that wagon will increase. Similarly, if the load on this wagon is reduced, its resistance to wheel unloading will also reduce. Train handling technique can also contribute to high longitudinal compressive forces within a train, especially when utilising dynamic braking on steep descending grades.

The relevant procedures and standards were analysed, not only to determine if actions conformed, but to identify their suitability to mitigate the derailment scenario identified through dynamic simulation and derailment evidence.

3.4.1 Train Loading/Train Marshalling

Code of Practice

The ACOP[11] requires an operator to put systems in place to ensure compliance with standard marshalling requirements. Of particular relevance are the requirements that state:

> *Vehicles with a gross mass on rail of less than 34 tonnes should, wherever possible, be marshalled towards the rear of freight trains*

And,

> *On the Adelaide-Melbourne-Sydney route, all vehicles with a gross mass on rail of 28 tonne or less shall be marshalled so that the trailing load on the foremost such vehicle is not more than 2600 tonnes.*

The intent of these requirements is to maintain the wagon stability such that the likelihood of derailment is minimised. A measure of wagon stability is determined by the ratio of lateral force divided by vertical force (L/V ratio). Among other elements, lateral force is affected by the amount of trailing load and subsequent longitudinal drawbar forces, which can translate into a lateral force component when the drawbar rotates in yaw. Vertical force is primarily affected by the gross mass of the vehicle. When the L/V ratio exceeds a critical value, the likelihood of derailment increases; therefore, it is highly desirable to marshal the lighter wagons to the rear of freight trains.

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[11] COP, Volume 3, Part 2, Section 8.2, Standard Marshalling Requirements

However, some ambiguity exists between the ACOP definition of a ‘vehicle’, and the application of that definition to multiple platform wagons such as Pacific National’s RQZY class wagon. The ACOP defines a ‘vehicle’ as:

> *... rail vehicles where reference to a specific type or class is not required or not intended.*

In short, a rail vehicle can equate to a wagon type. For example, the entire RQZY class wagon (5 platforms) can be interpreted as a single vehicle under this definition. This interpretation is reinforced by the ACOP definition of a ‘wagon’, or an ‘articulated wagon’, where it again implies that all platforms combine to form a specific type of rail vehicle.

Applying this interpretation contradicts the intent behind the marshalling requirements. The mass of an unladen multi-platform RQZY class wagon is 98 tonnes[12], which places this wagon outside the criteria documented in the ACOP marshalling requirements. However, from a wagon dynamics point of view, each platform of a multi-platform RQZY class wagon is in effect a separate vehicle, albeit with a solid drawbar instead of a coupler. The mass of an unladen platform is slightly less than 20 tonnes, which would place an individual platform within the criteria documented in the ACOP marshalling requirements.

The ACOP is a documented series of principles, guidelines and requirements developed specifically to encourage uniform practices for railway operations on the DIRN. Organisations should apply the requirements and the ‘intent’ of the ACOP, while considering their own operational requirements. This is reinforced within the ACOP where it states:

> *The Code of Practice should be used in conjunction with competent operational and engineering judgment. It is imperative that each user reviews the information herein in the specific context of the intended application in consultation with the relevant regulatory bodies, operators, owners and rail access providers.*

The ACOP has been developed over time, based on the collective experiences and practices of the organisations participating in its development. It is likely that some aspects of the ACOP have not been reviewed for many years. Consequently, these guidelines may not be consistent with the changes in modern rail operations, where modern locomotives are more powerful and have more efficient dynamic braking. The ACOP is not necessarily an industry ‘best’ practice, but rather an industry ‘agreed’ practice with ongoing review and development highly dependent on industry initiation and input. Again, this is reinforced within the ACOP where it states:

> *Responsibility rests with the rail organisation to ensure that all aspects of the Code are safe.*

Pacific National Procedures

Pacific National maintains a documented safety management system which includes documented procedures, published and distributed to each freight terminal. While these procedures document generic key requirements, the detailed processes

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[12] Pacific National Wagon Details Manual, WDM-RQZY_02, Issue date 21 Feb 2003

for implementing these requirements are managed by the individual terminals and may vary depending on each terminal's environment.

Pacific National has implemented two software tools to assist terminal personnel with managing train loading and marshalling:

'OASIS' - manages parameters dictated by rail corridor related limitations such as axle weights and height/width limits etc.

'TMS' - manages parameters dictated by train related limitations such as total train weight/length, draw gear limits etc.

The common sequence for load management is:

- The customer provides consignment details including container and cargo details.
- The 'Planner' allocates the consignment to a 'slot' in the train consist using OASIS and the information provided by the customer.
- The consignment arrives at the terminal and is weighed and loaded to the allocated slot using mobile container lifting vehicles. Identified variations to the consignment details (weight etc.) are updated in TMS.
- The 'Coordinator' checks the train consist using TMS and any other rules such as those documented in the Loading and Marshalling Requirements. The train is then 'confirmed' for departure.
- If the train cannot be confirmed, the Coordinator will reallocate the consignments to ensure that all rules are satisfied, thereby allowing the train to be confirmed.

Train 7MP5 was marshalled at the Melbourne Freight Terminal (MFT). However, due to yard layout limitations, the process described above has not been adopted at the MFT. The MFT does not have the ability to stable a complete 1500m train on one road and is therefore required to split the train over two roads. One road will stable the front half of the train while the other will stable the rear. Gantry cranes are used to load containers directly from the delivery trucks onto rail wagons.

To provide efficient use of the gantry cranes, a process called 'shot-gunning' has been adopted at the MFT. The process is summarised as:

- The customer provides consignment details including container and cargo details.
- The consignment arrives at the terminal and is weighed on entry and any variations to the consignment details updated.
- The crane operator then loads the heavier containers on the front half of the train and the lighter on the rear. The slot to which the container has been loaded is entered into TMS by the crane operator.
- The 'Yard Supervisor' checks the train consist using OASIS, TMS and any other rules such as those documented in the Loading and Marshalling Requirements. The train is then 'confirmed' for departure.
- If the train cannot be confirmed, the 'Yard Supervisor' will reallocate the consignments to ensure that all rules are satisfied, thereby allowing the train to be confirmed.

Both the standard process and the 'shot-gun' process rely on correct input of data to OASIS and TMS, followed by diligent checking against other documented requirements. Only after these checks are successfully verified can trains be confirmed and allowed to depart the terminal. Therefore, for either process, the critical issue in relation to correct loading and marshalling of trains are the rules incorporated into the software programs and other documented requirements.

While OASIS and TMS incorporate a number of rules related to the loading and marshalling of trains, they do not contain all rules required to be satisfied prior to a train being confirmed for departure. For example, at the time of accident, the software tools did not incorporate the rules aimed at managing in-train forces influenced by the train's load profile during train operations. These rules are documented in Pacific National's 'Loading and Marshalling Requirements'[13]. However, Pacific National has advised that future enhancements to TMS are likely to incorporate these requirements.

At the time of derailment, Pacific National's procedure for loading and marshalling specified maximum trailing load rules for the RQZY class wagon. Of particular relevance are the rules that state:

> *Trains shall be marshalled in accordance with the following requirements:-*
>
> *(c) Maximum trailing load behind an empty wagon on the Adelaide-Melbourne-Sydney-Brisbane corridor shall be 2600 tonnes.*
>
> *(d) Lightly loaded wagons shall, where possible, be marshalled to the rear of the train. On the Adelaide-Melbourne-Sydney-Brisbane corridor maximum trailing loads shall be limited as shown in Table 1 below*[14]*.*

Wagon RQZY7066 on train 7MP5 carried load on both end platforms with the centre three platforms unladen. The gross mass of RQZY7066 was 133.35 tonnes with a trailing load of 2959.40 tonnes. At the time of derailment, this configuration conformed to Pacific National's procedure for loading and marshalling, with the trailing load below the maximum permissible figure of 3300 tonnes specified in the table.

However, these rules are based on recognising the entire RQZY class wagon (5 platforms) as a single rail 'vehicle' under the ACOP definition. As previously described, this interpretation contradicts the intent behind the ACOP marshalling requirements. Consequently, the unladen platforms of RQZY7066 were not recognised as empty wagons for the purpose of applying Pacific National's procedure for loading and marshalling.

Pacific National has conducted a review of their procedures for loading and marshalling, and subsequently reissued the document on 7 December 2004. The amended procedure recognises the intent of the ACOP marshalling requirements by treating each platform of a multi-platform drawbar connected wagon as an individual wagon. In addition, Pacific National has reassessed the trailing loads

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[13] Pacific National Train Inspection Manual, Section TIM05-02, Loading and Marshalling Requirements, Issue Date; 28 June 2002

[14] Note: Table 1 not shown.

applicable to lightly loaded platforms whereby an unladen RQZY platform would now be limited to a trailing load of 1600 tonnes.

Table 5 shows the comparison between the Loading and Marshalling Requirements in force at the time of derailment (21 Nov 2004) and the amended requirements (07 Dec 2004), as applied to train 7MP5 (first 20 vehicles). As demonstrated, if the amended procedure is applied to 7MP5, five platforms are identified as exceeding the allowable trailing load applicable to their respective gross mass. Under the amended requirements, the train would not have been permitted to depart the Melbourne Freight Terminal until the load had been appropriately redistributed.

Table 5: Comparison of train conformance to the Loading and Marshalling Requirements

Slot Number	Vehicle Type	Loading and Marshalling Requirements as at 21 Nov 2004			Loading and Marshalling Requirements as amended 07 Dec 2004		
		Gross Mass	Trailing Load	Pass/Fail	Gross Mass	Trailing Load	Pass/Fail
1-4	Locomotives						
5	5-pack well	133.35	2959.40	Pass	46.1	2959.40	Pass
6	5-pack well				19.6	2913.30	Fail
7	5-pack well				19.6	2893.70	Fail
8	5-pack well				19.6	2874.10	Fail
9	5-pack well				28.45	2854.50	Fail
10	5-pack well	215.78	2826.05	Pass	31.08	2826.05	Fail
11	5-pack well				41.42	2794.97	Pass
12	5-pack well				45.98	2753.55	Pass
13	5-pack well				50.02	2707.57	Pass
14	5-pack well				47.28	2657.55	Pass
15	Single	47.68	2610.27	Pass	47.68	2610.27	Pass
16	Single	40.00	2562.59	Pass	40.00	2562.59	Pass
17	Single	27.22	2522.59	Pass	27.22	2522.59	Pass
18	Single	18.60	2495.37	Pass	18.60	2495.37	Pass
19	Single	29.94	2476.77	Pass	29.94	2476.77	Pass
20	Single	25.35	2446.83	Pass	25.35	2446.83	Pass

Note: data sourced from Pacific National’s train management system

Load Measurement

If the processes are followed correctly and the rules are correct, the next critical issue is the reliability of the load measurement.

As part of the investigation, a ‘Train Consist Report’ was obtained from Pacific National’s TMS software, and data sourced from the ARTC’s Wayside Impact and Load Detection (WILD) system located at Lara, near Geelong VIC. However, a significant variation was identified between the load measurements recorded by the ARTC WILD system and the loads recorded by Pacific National (Refer Table 6).

Table 6: Load measurement comparison

Source of measurement	Load
Pacific National TMS	2959.4 tonne
ARTC WILD	3227.9 tonne

The mass entry in Pacific National's TMS is determined by the consignment mass as measured by a weighbridge on entry to the freight terminal. Within TMS, this entry is added to the designed tare mass of the wagon on which the consignment is loaded. The accuracy of the TMS value is therefore dependent on the accuracy of the tare mass figure and the accuracy of the weighbridge.

Pacific National has four weighbridges at the Melbourne Freight Terminal. Each of these were certified by NATA-registered Mettler-Toledo Ltd, between November 1 and November 9, 2004.

The tare mass specified for a wagon class is generally the theoretical design mass. While it could be reasonably assumed that the theoretical tare mass would be consistent with the actual tare mass, it does present some level of uncertainty.

The ARTC's WILD system, developed by Teknis Electronics Pty Ltd, uses a hybrid sensor array consisting of accelerometers and load cells that measure wheel impact and mass respectively, as each axle traverses the array. This information is stored in a database for further analysis.

A presentation by Teknis[15] indicated that in addition to in-motion weighing, the system can be further enhanced to automatically generate an alarm when defined criteria are exceeded. This includes generating alarms when lightly loaded vehicles are detected within a heavy consist.

The accuracy of the WILD system is dependent on calibration using trains hauling certified reference wagons. The ARTC advised that the last calibrated weighing of three trains was in June 2004. Comparison with data recorded at the three ARTC WILD sites, together with similar tests conducted on coal lines in Queensland, allowed Teknis to develop and install updated system software in September 2004. Further calibration tests have not been conducted. Therefore, the accuracy of the ARTC WILD systems cannot be verified.

While neither load measurement system can be considered absolutely accurate, there is still a role for both systems in mitigating the risks presented due to loading and marshalling of trains:

- Pacific National through diligent checking of trains prior to departure. Incorporation of rules and requirements into the software tools (OASIS and TMS) would assist terminal personnel in conducting these checks.
- The ARTC through implementation of remote alarming due to lightly loaded wagons detected within heavy consists. Subsequent and timely advice to operators would then allow appropriate operational processes to be implemented to mitigate any detrimental risks.

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[15] International Symposium on Transportation Recorders, Arlington, Virginia, May 1999 http://www.ntsb.gov/events/symp_rec/proceedings/authors/lechowicz.pdf

3.4.2 Train Handling

A freight train is a complex system of vehicles, the dynamics of which are dependent on many factors such as:

- marshalling of wagons, loaded or empty
- length of the train
- curvature and gradient of the track
- condition of the track
- weather conditions
- locomotive characteristics
- train handling skills of the driver (throttle, braking etc.)

Good train handling over a given terrain is achieved through proper use of the air brakes (both automatic and independent), dynamic brake, combinations of air and dynamic braking, throttle and other controls. To ensure in-train forces on the track, vehicles and locomotives are minimised, the locomotive driver must plan and anticipate actions well in advance of the train's current position. Therefore, success is dependent, not only on equipment condition, but more importantly on a driver's judgement, skill and route knowledge.

Rarely would two trains or operating environments ever be identical. As such, documented standards for train handling are usually provided in the form of generic information that may be applied to the majority of situations. Pacific National's Train Handling Standards[16] follow this philosophy and is presented as a reference manual, containing general information, instructions, guidelines and procedures for the safe and efficient management and operation of trains operated by Pacific National.

The questions to be addressed are:

- Was 7MP5 handled in a manner consistent with the documented procedures?
- Was 7MP5 handled in a manner appropriate to the terrain it was negotiating?

The track leading into Adelaide from Melbourne incorporates some of the steepest gradients and tightest curves existing on the DIRN. For example, the 8km section from Mount Lofty to the point of derailment at Belair requires trains up to 1500m in length and 5000 tonnes to negotiate more than 20 reverse curves between 190m and 240m radius, while descending a continuous 1 in 45 gradient.

Pacific National's standard indicates that in most cases, dynamic braking may be used as the sole means of controlling train speed on descending grades. In fact, the use of dynamic braking is encouraged for fuel efficiency plus it eliminates problems associated with train braking such as wheel wear, overheating wheels, and brake block wear. The key requirement when operating a freight train down long grades is to maintain a consistent, safe, steady speed while maintaining an ample safety margin suitable for stopping the train anywhere on the grade if required.

At 1473m in length and 2960 tonnes (trailing load), 7MP5 had been consistently travelling well below the posted speed limit (50km/hr) for this section of track. At

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[16] Pacific National - Train Handling Standards, Document No. THS_01-R03, 4 May 2004

the point of derailment, 7MP5 was travelling at a constant 42 km/hr. It was evident that both the independent and automatic air brake systems were not applied throughout 7MP5's descent[17], with the locomotive's dynamic braking utilised to balance the train's speed. Both train speed and braking effort were relatively constant as the train traversed the derailment location. It was evident that the driver was familiar with the route and was aware of the terrain ahead[18] such that smooth subtle adjustments were applied to manage the train's progress.

In general, assuming no undesirable influences, the driver managed the operation of 7MP5 down the descending grade towards Adelaide in accordance with Pacific National's documented standards. However, not all factors relating to 7MP5 were desirable. 7MP5 had been marshalled with three empty platforms on the 5-unit well wagon coupled immediately following the locomotives.

The principal responsibility for ensuring a train has been marshalled correctly lies with the relevant freight terminal. The locomotive drivers only take responsibility for the train once it has been 'confirmed' for departure, at which stage the driver would, quite rightly, assume the train has been marshalled appropriately. Short of physically inspecting the train, the only document a driver can refer to, that may give any indication of undesirable load distribution, is the Train Consist Report[19]. However, the report's rollingstock information provides no indication of gross mass for individual platforms within multiple platform wagons.

Similarly, the Load Distribution Diagram within the Train Consist Report also indicates the gross mass of an entire multiple platform wagon and not individual platforms. Figure 16 illustrates the load distribution of 7MP5 in a similar format as that displayed in the Train Consist Report. Note that the upper two load bars (labelled 1-5 and 6-10) correspond to the first two multi-platform wagons coupled immediately following the locomotives. From the diagram, the load of the first two wagons would seem to be greater than 130 tonnes and 210 tonnes respectively. However, each of these loads represents the total gross weight of five individual platforms.

It is also impossible to use the Load Distribution Diagram as a tool for identifying all empty or lightly loaded rail vehicles within the train consist. In most cases a wagon weighing less than 20 tonnes would usually be empty. When referring to the Load Distribution Diagram in Figure 16, only wagon (Number 14) is less than 20 tonnes. However, the diagram does not illustrate the three empty platforms that existed in the multi-platform wagon labelled 1-5.

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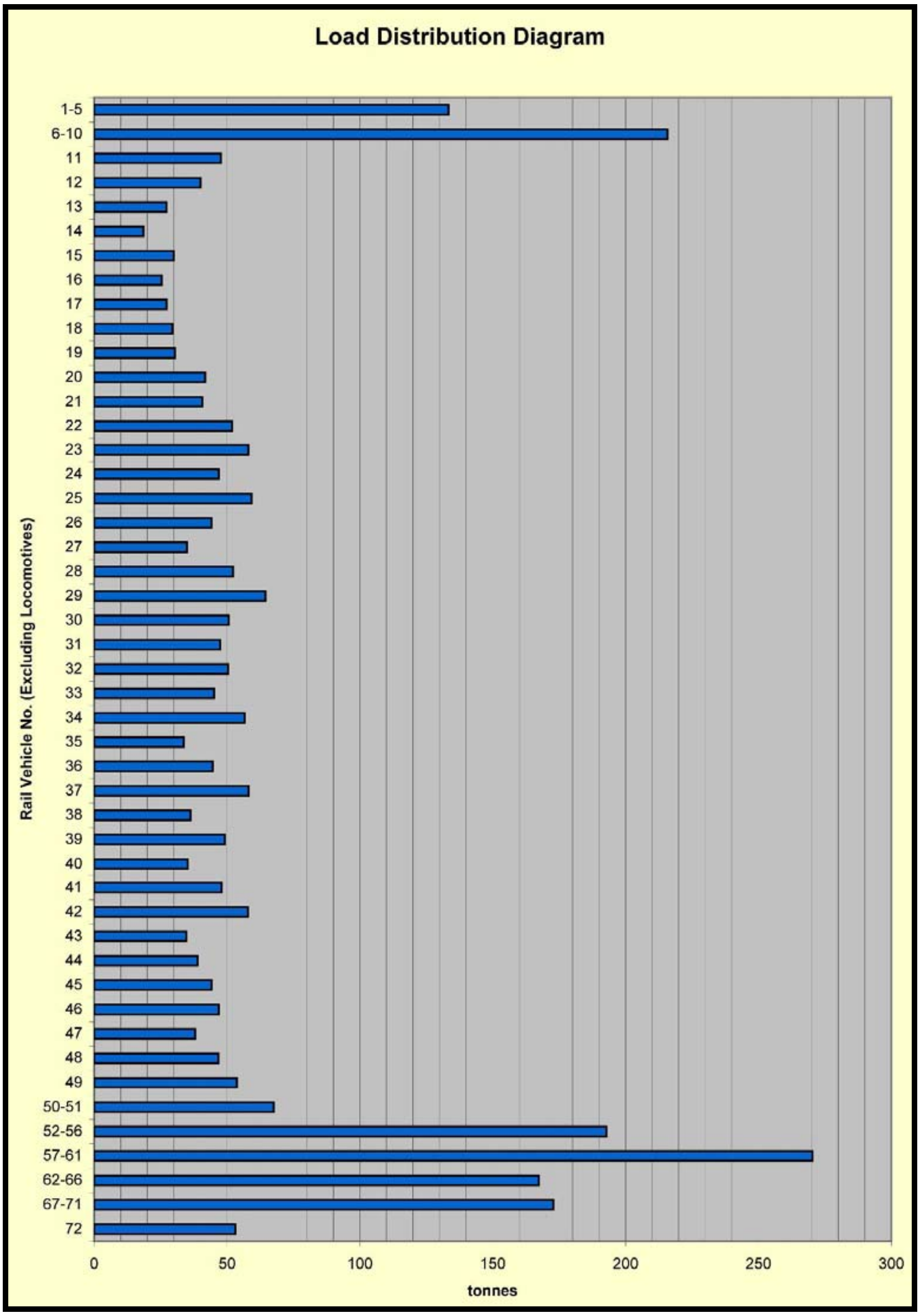
[17] Obtained from NR11 locomotive data log and verified against NR31 locomotive data log

[18] Driver interviews conducted following the derailment

[19] TMS – Yard Management System – Train Consist Report

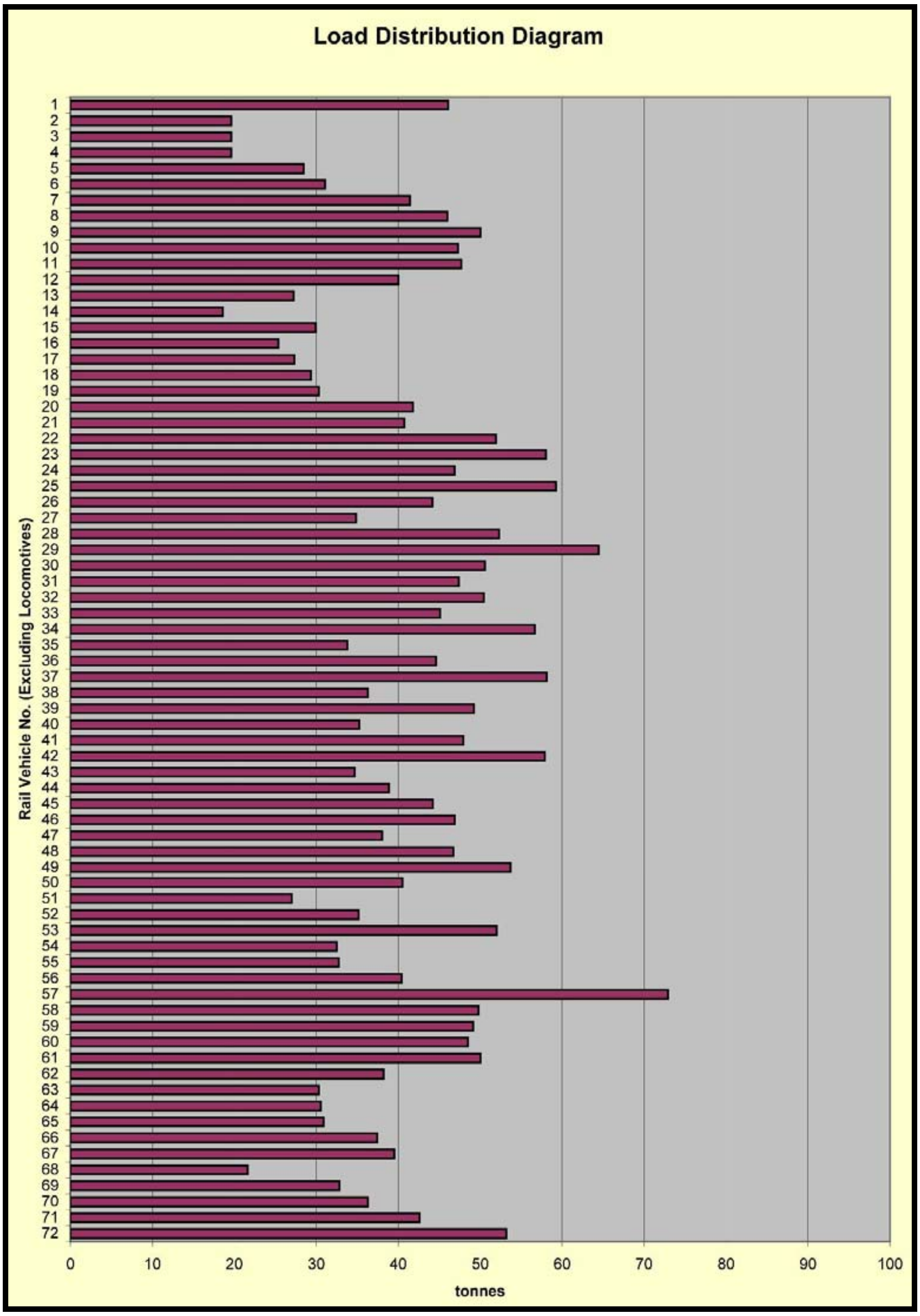
Figure 16: Load distribution diagram similar to that displayed in 7MP5 Train Consist Report



It would seem that, currently, the primary purpose of the Train Consist Report is to provide a driver with total train mass and length information and, if required, the location and classification of any dangerous goods. If the Train Consist Report were to provide information relating to each wagon and platform, a more accurate indication of the train's load distribution would be available to the driver. The driver could then tailor the driving technique to reflect any undesirable factors relating to the load distribution.

Figure 17 illustrates the load distribution of 7MP5 in a format where each platform within a multi platform wagon is displayed. In this diagram rail vehicle numbers 2, 3 and 4 are clearly displayed as weighing less than 20 tonnes and correspond to the empty platforms within the first multi-platform wagon coupled immediately following the locomotives. (Note the different load scale to that displayed in Figure 16)

Figure 17: Load distribution diagram of 7MP5, if each platform within a multiple platform wagon were displayed



Pacific National's standard recognises train marshalling as a key factor in managing in-train forces. Numerous entries throughout the document make reference to the desirable marshalling practice of placing the heaviest wagons closest to the locomotives and the lightest (empty) wagons towards the rear. Similarly, the document recognises that dynamic braking can contribute to high buff forces[20] and subsequent high lateral forces especially while negotiating curves or turn-outs. Again, numerous entries identify these forces as contributing factors to derailment due to flange climb, track spread or the back of a flange riding up onto a check-rail.

Pacific National's standard makes a number of references to supplementing the dynamic brake with an automatic brake application to distribute braking and in-train forces throughout the train rather than concentrating them at wagons immediately following the locomotive. This is especially the case where there is a high degree of curvature, as demonstrated by the following quotation from Pacific National's train handling standards.

> *The dynamic brake should be reduced from maximum proportionately to curvature, before entering and until one half of the train has negotiated a sharp turnout, crossover or curve.*
>
> *This is particularly important if the dynamic brake is used entirely for controlling the speed of train and the train has a combination of long and short wagons, and/or empties or light loads on the head end and heavy loads on the rear end. Under these conditions, a harsh bunching of slack or run-in, combined with the curvature, can cause very large L/V ratios[21] and possibly cause derailment or damage to track structure.*
>
> *For these reasons, when these conditions apply, dual braking is the preferred mode.*

Based on Pacific National's documented train handling standards, the use of dual braking may have been the most appropriate method of managing 7MP5 down the descending grade towards Adelaide.

3.5 Signalling and Communication

The investigation determined that the ARTC's signalling and communication systems had operated correctly and did not contribute either directly or indirectly to the derailment of 7MP5. Similarly, the communication systems operated correctly immediately following the accident and throughout the post accident response and recovery. It was evident that the operation of the communication systems did not contribute to any increased risk of further damage or injury. However, it is recognised that due to the freight line and passenger line running in close proximity to each other, any potential failure for the ARTC and TransAdelaide to effectively communicate could increase the risk of further damage or injury.

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[20] The forces generated through compression or bunching of wagons

[21] L/V is the ratio of Lateral and Vertical forces

Effective communication has been a focus of the rail industry for some time, not only in relation to train control and safe-working but accident and emergency response. It is not the intent of this investigation to delve into the intricacies of the communication systems in service, but rather to analyse the effectiveness of the relevant systems associated with this specific accident. However, to give context to the analysis, reference to the railway industry's broader strategic direction is relevant.

The Australasian Railway Association (ARA) has been tasked with the development of a Code of Practice on railway communications. While data-based communication is recognised as reducing the reliance on voice communication, it is also recognised that voice communication will continue to be an important feature, especially in an emergency. With this in mind, the ARA conducted industry surveys to determine the minimum functionality of future voice communication systems. The outcome of this process is summarised as:

- There must be the capability for voice communication between train control and trains, or other on-track vehicles. This communication must be recordable.
- Train control must be capable of making targeted group broadcasts in these areas, either through group broadcast calling or open channel communication.
- The track owner's train communication system must be capable of prioritising emergency calls.
- Train control should have a communication system capable of taking and making calls on the track owner's own communication system or any publicly available voice network that meets the minimum requirements.
- Train to train or train to wayside based local communication is considered highly desirable for emergency situations.

A recognised challenge is the operation of long-haul freight trains in and through multiple urban/metropolitan passenger rail networks, or as in this case, along an adjacent line. Urban rail systems are generally high volume with heavy communications requirements. These conditions usually demand a dedicated communications network. Herein lies the problem of voice communication over differing communication systems (Inter-operability).

The ARA position for inter-operability is:

> *Responsibility for determining inter-operability between different technological communication solutions will be the responsibility of the track manager. This is based on the position that it is easier to deal with a number of communication technologies at the train control centre rather than requiring operators to be equipped with a number of systems on the locomotive.*[22]

This does not mean that railway operators would have unilateral choice as to their communications technology and that the track mangers must provide for it. The

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[22] ARA Railway Communications Strategic Framework

intent is that suitable systems are put in place allowing effective communication, either directly or indirectly, between train control and 'foreign'[23] trains.

The DIRN section from Belair, through Glenalta, to Adelaide runs adjacent to Adelaide's broad gauge metropolitan passenger line. The train control function over the DIRN section is provided by the ARTC, while TransAdelaide provides the train control for the metropolitan passenger line. Both ARTC and TransAdelaide use UHF radio for voice communications between trains and train control; however, each organisation has been allocated different frequencies. This is an example of the inter-operability problem documented by the ARA. Both systems generally conform to the minimum requirements listed above, except that they cannot communicate with each other directly.

The derailment of 7MP5 demonstrates the importance of addressing the issue of inter-operability over differing communication systems. As described in section 2.3 (The Occurrence) two freight wagons impacted with TransAdelaide's passenger facilities with five wagons finally coming to rest while obstructing the adjacent metropolitan passenger track. Had passengers been waiting at the Glenalta railway station, or a passenger train been located at the station, the risk of injury to the public would have been significant. Similarly, while communication was not considered a contributory factor in the derailment itself, failure to communicate the accident to the passenger network could substantially increase the possibility of a passenger train colliding with wreckage at the derailment site.

The potential for injury, due to a derailment on one line fouling the other, is demonstrated by considering TransAdelaide's passenger service timetable. The derailment occurred on a Sunday at approximately 1006. This places the closest passenger train approximately 20mins away, giving ample time to notify TransAdelaide train control. However, had the accident occurred at the same time on a weekday, the outcome could have been substantially different, since timetabled trains were due at the Glenalta railway station at 0959 and 1015.

Figure 18: Damaged pedestrian crossing and passenger platform at Glenalta Railway Station

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[23] 'Foreign' refers to trains that are not under direct management of a specific train control. For example, trains are 'foreign' to one train control if they are on an adjacent rail network managed by a different train control.

The issue of communication between the ARTC and TransAdelaide has been the subject of discussion between the respective organisations for some time. Sharing a rail corridor with adjacent lines exposes both organisations to risks in the event of an accident such as the derailment of 7MP5. TransAdelaide is committed to adopting the South Australian Government Radio Network (SAGRN) for its voice communication requirements. Unfortunately, the SAGRN radios are not in the same frequency band as the ARTC radios, making it impossible to include a common channel for communication.

It is operationally desirable that TransAdelaide train controllers are aware of, and have a level of communication with, train movements over the ARTC network between Belair and Adelaide. This is due to an interface where the ARTC line crosses the TransAdelaide line. This interface comes under TransAdelaide's jurisdiction, thereby requiring TransAdelaide train controllers to manage both the ARTC and TransAdelaide train traffic traversing the interface location. While this location may be some 16km beyond Belair, it is important that TransAdelaide controllers be aware of an approaching ARTC movement to allow planning of the cross between passenger services.

To achieve this operational requirement, a UHF radio programmed with the ARTC frequency is located at TransAdelaide's train control. This allows TransAdelaide train control staff to communicate with both the ARTC control and, if necessary, trains communicating over this ARTC frequency. Alternatively, telephone communication can be utilised between the ARTC and TransAdelaide train control staff.

While this goes some way towards addressing the inter-operability risk, it does not allow the prioritisation of emergency calls. Prior to the derailment on 21 November 2004, the ARTC and TransAdelaide had already initiated further action to control the inter-operability risk. While not fully commissioned at the time of the derailment, a SAGRN radio console, programmed with a dedicated emergency channel, had been installed at the ARTC Train Control. This emergency facility, through activation by either the ARTC or TransAdelaide, will trigger an audible alert and allow normal voice conversation between respective train control staff. If necessary, either TransAdelaide or the ARTC operational channels may be 'patched' together to enable either user to monitor communications directly.

The voice recordings from both the ARTC and TransAdelaide train control communication systems were obtained and the effectiveness of the communication systems analysed.

Recognising the risk posed by the obstruction to TransAdelaide's passenger network, the driver of 7MP5 first attempted to contact TransAdelaide train control via the UHF radio. However, receiving no immediate response, the driver then called for the ARTC control. Both times, the driver used the phrase *"…emergency, emergency, emergency…"* to draw attention to the importance of the communication. Communication with the ARTC train control was brief, concise, and provided information regarding the accident location, while also highlighting the potential risk to the adjacent TransAdelaide network. The ARTC train control then contacted TransAdelaide via the UHF radio, who in turn contacted the relevant metropolitan passenger services. The total time from the 7MP5 driver's first communication attempt to the completion of communications to the passenger service was less than three minutes.

It should be noted that TransAdelaide was immediately aware that something had occurred in the Glenalta area. TransAdelaide's network is fully signalled and track circuited providing train control with indication of the entire network. When 7MP5 derailed, the damage it caused to TransAdelaide's infrastructure provided immediate indication to TransAdelaide's train control. It is likely that the controller's attention, being drawn to the unexpected indications, resulted in the initial delay in responding to the 7MP5 driver's call, by which time contact with the ARTC had been achieved. TransAdelaide, having monitored the communication to the ARTC, had already started identifying the passenger services likely to be affected and following their subsequent communication with the ARTC, were able to immediately implement an appropriate response to protect the TransAdelaide services. It should also be noted that the damage sustained to the TransAdelaide signalling system at Glenalta would have caused all relevant signals to show a 'Stop' indication, thereby providing an additional level of protection to the passenger services.

3.6 Accident Response

3.6.1 Procedures

The documented procedure used to guide the response to the derailment of 7MP5 was the ARTC's Accident Management Manual[24] (TA44). ARTC require operators, service providers or maintenance providers to use TA44 as their primary high level document for managing accidents. While these organisations may have their own accident response plans, these are required to be complementary to the ARTC's TA44.

The first response when an employee[25] becomes aware of an accident is to ensure the site is protected and to immediately contact train control. In relation to the derailment of 7MP5, the driver's first response, recognising the immediate risk posed by the obstruction to TransAdelaide's passenger network, was to attempt to contact TransAdelaide train control via the UHF radio. It is not uncommon for freight operators in this area to communicate directly with TransAdelaide train control in preparation for traversing passenger network interfaces under the control of TransAdelaide, located further down track. In this case, the driver was unable to make immediate contact with TransAdelaide train control and proceeded to make contact with the ARTC train control as required under TA44.

Following a report to the ARTC train control, the Train Transit Manager (TTM) is immediately advised and becomes the principal coordinator of actions from that time. Note that the responsibility for some functions may pass to other personnel as time progresses, for example a Site Co-ordinator. In relation to the derailment of 7MP5, the TTM utilised the appropriate check list[26] to assist in the management of the accident. It is evident from this record that the appropriate organisations were promptly advised and the contact details of on-site personnel were identified.

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[24] ARTC – Accident Management Manual, Document TA44, Version 4.1, 13 September 2004.

[25] Employee means an employee of ARTC, an operator, service provider or maintenance provider.

[26] ARTC form TAFO-02-2, Train Transit Manager – Major Accident Log, Issue Date March 2004.

It is not clear as to when the ARTC train control reported the accident to the emergency services and subsequently requested their attendance. Similarly, TransAdelaide train control did not initiate a call to emergency services. However, an officer of the Transit Police[27] called TransAdelaide train control within three minutes of the derailment and requested further information. This call would have been prompted by a '000' call logged at the Police Communication Centre at 1006, almost immediately following the derailment. This call most likely originated from a motorist[28] who witnessed the derailment at the Glenalta level crossing. Similarly, it is evident that Ambulance and Country Fire Services were also indirectly notified, as both contacted TransAdelaide over the following 30 minutes seeking further information.

Figure 19: View of road where motor vehicles and witnesses were waiting at the level crossing

Since this derailment occurred within Adelaide's metropolitan area, it is not surprising that emergency services would receive calls from on-site witnesses prior to either train control being fully aware of the relevant details. However, had the accident occurred in a less populated area, the primary responsibility for emergency services notification would lie with the respective train control.

Following the initial report to train control, the drivers of 7MP5 continued to ensure the site was protected and to identify potential injuries that may have been sustained to members of the public. Having identified the existence and location of any dangerous goods, the drivers proceeded to walk back from the locomotives to ensure that no potential existed for spillage of this freight. Following confirmation that loads containing dangerous goods were safe, the drivers attempted to protect the site from public access.

When accidents occur in a metropolitan area, response by emergency services can, and in this case did, occur quite quickly. However, high public profile locations can generally initiate an even quicker public interest response, making the driver's job of site protection difficult until the arrival of Police. In general, accident management following the derailment of 7MP5 was conducted in an efficient and professional manner. This includes the actions of drivers, train control staff, and emergency services.

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[27] South Australia Police, Transit Services Branch - responsible for provision of police services for the public transport systems in Adelaide.

[28] Two motorists, who witnessed the derailment while waiting at the level crossing, were interviewed.

3.6.2 Site Recovery

Both freight and passenger rail networks are transportation modes vital to many organisations, the disruption of which can create roll-on effects throughout many industries. It is therefore important that restoration works are carried out quickly and efficiently. However, just as important is the investigation and identification of safety measures to help prevent a future recurrence of a similar accident. To achieve an appropriate outcome, the investigation should not prevent prompt recovery work, and similarly the recovery work should not contaminate essential evidence required for the investigation.

Figure 20: View of rollingstock in private property and recovery process

In relation to the derailment of 7MP5, the site recovery phase was conducted in an efficient, coordinated and professional manner. All parties cooperated in a manner that allowed items of interest to be identified and recovered in a manner appropriate to allow future examination and analysis. Normal ARTC operations resumed at approximately 1930 on 23 November 2004, while TransAdelaide's metropolitan passenger services resumed on 25 November 2004.

3.7 Previous Accidents

It is important that the rail industry is aware of safety issues identified from investigation of previous accidents. This allows the identification of common themes which, when analysed, may lead to the implementation of safety measures aimed at preventing recurrence. With this in mind, a search and review of previous accident investigations was conducted, focusing on accidents similar in nature or geographic location.

One previous accident was identified which was considered similar in nature to the derailment of 7MP5. This accident also occurred near Glenalta, SA.

22 October 2002 – Derailment of 2MP5 – Glenalta, SA

At approximately 0925 on 22 October 2002, Pacific National freight train 2MP5 derailed in the Adelaide Hills between Glenalta and Blackwood railway stations. Freight train 2MP5, hauled by three locomotives, was travelling from Melbourne to Adelaide and consisted of 3086 trailing tonnes with a total train length of 1316 metres. An investigation was conducted into the accident, with a joint investigation team consisting of representatives from Pacific National, ARTC and Transport SA (Independent Chair).

Figure 21: Derailment of 2MP5, Glenalta SA, 22 October 2002

The investigation determined that the cause of the derailment was the trailing end of the empty second platform of a 5-unit wagon lifting sufficiently to allow the leading end of the third platform to be forced underneath it. High dynamic braking forces accompanied by large trailing loads behind an empty platform were identified, among others, as contributing factors.

It should be noted that this investigation also made reference to the ambiguity in the ACOP definition of a ‘vehicle’, and the application of that definition to multiple platform wagons (Refer to section 3.4.1 Train Loading/Train Marshalling). The investigation report documents the observation that:

> *… given the lack of specific reference to individual platforms on these types of wagons, it would appear to be reasonable to treat individual platforms as wagons or vehicles for the purpose of calculating trailing loads and for marshalling requirements.*

However, the report goes on to observe that:

> *Pacific National considers this logic to be conservative and overly simplifies the issue and does not recognise the loading forces at the bogie as opposed to the platform.*

Pacific National's proposed safety actions only covered RQWY and RRFY multiple-platform wagons and stated that all platforms were to be loaded when operating through the Adelaide hills. This action was to remain in force until a review of the ACOP had been completed, prescribing the loading and marshalling specifications for multi-platform wagons. It would appear that the two specific classes of 5-unit wagon were identified due to their relatively short drawbars between platforms, and the contributing effect the short drawbar had in relation to this accident.

To address the potential risk related to other classes of multi-platform wagons, the report recommended that Pacific National conduct its own review in light of the ACOP's lack of loading and marshalling specifications for multi-platform wagons. It is evident that Pacific National had initiated safety actions to establish loading and marshalling criteria for multi-platform wagons[29]; however, these actions were yet to be completed and implemented.

Following the derailment of 7MP5 on 21 November 2004, Pacific National completed their review of the loading and marshalling procedures, and subsequently reissued the document on 7 December 2004. The amended procedure recognised the intent of the ACOP marshalling requirements by treating each platform of a multi-platform drawbar connected wagon as an individual wagon.

Had these safety actions been implemented prior to 21 November 2004, the derailment of 7MP5 may not have occurred.

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[29] Pacific National, Risk Mitigation Action Plan, dated 3 October 2003

4 CONCLUSIONS

As a result of its investigation, the ATSB makes the following observations detailing the most likely cause of the derailment, the factors believed to have contributed to the derailment, and any other factors of interest identified through analysis.

4.1 Likely Cause of Derailment

The most likely direct cause of the derailment of 7MP5 was significant wheel unloading as a wheel made contact with a check-rail at the entrance to the Belair crossing loop. Wheel lift was sufficient to allow the wheel to become airborne and land with its flange tip on top of the check-rail, allowing the wheel set to shift laterally and for the opposite wheel to travel up the wrong side of the Vee and subsequently derail.

4.2 Contributing Factors

The investigation determined that a number of factors combined to contribute to this particular derailment. Any one factor in its own right is unlikely to have resulted in a derailment, but the four factors acting together greatly increased the likelihood of derailment.

1. Wagon RQZY7066, with three empty platforms, was coupled immediately following the locomotives of 7MP5. Almost 2900 tonnes of trailing load was present behind the empty platforms, which exceeds the limit of 2600 tonnes stipulated by the ACOP marshalling requirements.
2. The use of dynamic braking as the sole means of controlling train speed on the descending grade exerted significant longitudinal compressive forces on the RQZY wagon, with three empty platforms, coupled immediately behind the locomotives.
3. In tare condition, the RQZY wagon is relatively light weight, rides on very stiff vertical suspension, and exceeds the maximum CCSB pre-load recommended by the ACOP. It is likely that the very stiff vertical suspension reduces the ability of an empty RQZY wagon to absorb discrete wheel impacts, such as the interface with a check-rail.
4. Track geometry influenced the oscillating motion of rollingstock, causing the right hand wheel flange into rail contact as the left hand wheel came into contact with the check-rail. It is likely that track irregularities only served to influence the timing of this movement, such that peak lateral forces occurred as the wheel came into contact with the check-rail.

4.3 Findings

The following findings may not have directly contributed to the derailment of 7MP5. However; they are documented with the intention that further opportunities for improvement to operational railway safety may be identified.

1. There was no indication of any fault, defect or deficiency that would indicate that the rollingstock was not fit for purpose on the day of the accident.
2. Examination of rollingstock identified uneven flange wear to a single wheel on two unrelated bogies. Neither wheel exceeded the minimum standard nor contributed to the derailment.
3. The Australian Code of Practice is ambiguous in its definition of a ‘vehicle’, in that the application of the definition can be read as applying to multiple platform wagons or a single rail vehicle.
4. The Pacific National software tools, OASIS and TMS do not currently contain all rules required to be satisfied prior to a train being confirmed for departure.
5. The Train Consist Report provides limited load distribution information to the train driver to enable them to tailor the driving technique.
6. The curve leading into the turn-out where 7MP5 first derailed is non-transitioned with all the cant runout within the curve.
7. 7MP5 was travelling at a constant 42 km/hr through the curve leading into the turn-out. Based on existing track geometry the maximum allowable speed for the curve at Belair is 35 km/hr, 15 km/hr less than the posted speed.
8. Simulation indicated that 7MP5 did not derail due to flange climb and that without the influence of the check-rail 7MP5 would likely have negotiated the location without incident.
9. Track gauge through the turn-out was compliant with the ARTC standards and the Australian Code of Practice. Similarly, the back to back measurements for the RQZY wheel-sets were compliant with the ACOP.
10. Analysis of the curve immediately prior to the Belair crossing loop identified three non-compliances against the ARTC standards and the Australian Code of Practice. None of these defects directly contributed to the derailment:
    - The posted speed for the curve was excessive based on the existing track geometry.
    - The rate of change of cant deficiency 20 m from the tangent point was excessive.
    - The track gauge measurement 200m from the tangent point just exceeded the requirement documented in ARTC’s standard.
11. The WILD system does not currently provide automatically generated alarms when lightly loaded vehicles are detected within a heavy consist.
12. The derailment occurred within Adelaide’s metropolitan area. Consequently, on-site witnesses contacted emergency services before train control could.

13. The site recovery phase was conducted in an efficient, coordinated and professional manner.

14. An accident similar in nature to the derailment of 7MP5 occurred on 22 October 2002 in the Adelaide Hills between the Glenalta and Blackwood railway stations.

5 SAFETY ACTIONS

As a result of its investigation, the ATSB makes the following recommendations with the intention of improving railway operational safety. Rather than provide prescriptive solutions, these recommendations are designed to guide interested parties on the issues that need to be considered. Recommendations are directed to those agencies that should be best placed to action the safety enhancements intended by the recommendations, and are not necessarily reflective of deficiencies within those agencies.

5.1 Actions Taken

Pacific National has conducted a review of their procedures for loading and marshalling, and subsequently reissued the document on 7 December 2004. The amended procedure recognises the intent of the marshalling requirements documented in the Australian Code of Practice by treating each platform of a multi-platform drawbar connected wagon as an individual wagon. In addition, Pacific National has reassessed the trailing loads applicable to lightly loaded platforms. Pacific National has also advised that future enhancements to their software tools (OASIS and TMS) are likely to incorporate additional rules.

5.2 Recommendations

RR20050043

The ATSB recommends that Pacific National:

- Review any ambiguity regarding the ACOP definition of a ‘vehicle’, and the application of that definition to multiple platform wagons.
- Review the loading and marshalling requirements, with consideration given to the intended application of the ACOP’s Standard Marshalling Requirements and with consideration given to modern rail operations.
- Implement the relevant changes and initiate the ACOP change process using the Code Management Company’s documented procedures.

RR20050044

The ATSB recommends that Pacific National enhance the functionality of the OASIS and TMS systems by incorporating the criteria for confirming a train for departure (including the loading and marshalling criteria).

RR20050045

The ATSB recommends that Pacific National:

- Enhance the Train Consist Report provided to locomotive drivers such that each platform of a multi-platform drawbar connected wagon is presented as an individual wagon.
- Encourage drivers to refer to the Train Consist Report and tailor their driving technique to reflect any undesirable factors relating to the load distribution, such as the use of dual braking on steep descending grades.

RR20050046

The ATSB recommends that Pacific National conduct further investigation and review into the suspension configuration of the RQZY wagon and similar wagons, with consideration to:

- the wagons’ ability to handle discrete wheel impacts when in tare condition
- the wagons’ ability to handle twisted track when loaded with a light weight empty container, noting that the wagon body would no longer retain its tare condition flexibility.

RR20050047

The ATSB recommends that the ARTC review the calculated and published speed limits for curves in areas of steep gradient, especially curves that are non-transitioned with all the cant runout entirely within the curve.

RR20050048

The ATSB recommends that the ARTC:

- Enhance the functionality of the WILD system to include automatically generated alarms when defined criteria are exceeded. For example, generating alarms when lightly loaded vehicles are detected within a heavy consist.
- Document and implement appropriate procedures for managing automatically generated alarms when defined criteria are exceeded.

RR20050049

The ATSB recommends that the South Australian Rail Safety Regulator:

- Actively monitor the actions initiated by organisations in response to this investigation.
- Recognise that the findings of this investigation may be relevant to other rail organisations or regulatory jurisdictions, and take the appropriate actions to ensure they are advised accordingly.

6 SUBMISSIONS

Section 26, Division 2, and Part 4 of the *Transport Safety Investigation Act 2003*, requires that the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate, for the purposes of:

a) Allowing the person to make submissions to the Executive Director about the draft: or

b) Giving the person advance notice of the likely form of the published report.

The final draft of this report was provided for comment to the following directly involved parties:

a) Pacific National

b) Australian Rail Track Corporation

c) TransAdelaide

d) South Australian Railway Safety Regulator

A number of comments and observations on the draft report were received from directly involved parties. Their remarks have been evaluated and considered by the ATSB investigation team and have been largely incorporated into the body of this report where appropriate.

7 APPENDICES

7.1 Measured Curve Detail

Distance ahead of switch point	Actual cant	Versine on 10m chord		Curve radius			Equilibrium cant	Cant deficiency
		Left rail	Right rail	Left rail	Right rail	Average		
00	25							
05	9	16	11	781	1136	958	31	22
10	18	19	22	658	568	613	48	30
15	22	43	40	291	312	301	98	76
20	25	67	70	187	178	182	162	137*
25	34	66	62	189	202	195	152	118
30	44	64	75	195	167	181	163	119
35	48	71	57	176	219	197	150	102
40	51	51	60	245	208	226	131	80
45	51	53	54	236	231	233	127	76
50	60	43	43	291	291	291	102	42
55	59	62	59	202	212	207	143	84
60	68	45	47	278	266	272	109	41
65	69	53	55	236	227	231	128	59
70	70	55	53	227	236	231	128	58
75	70	48	48	260	260	260	114	44
80	66	49	50	255	250	252	117	51
85	59	56	58	223	216	219	135	76
90	66	42	40	298	312	305	97	31
95	70	61	57	205	219	212	139	69
100	71							

Notes:

Curve radius = calculated from versine measurements

Average curve radius: in a short bogie the leading wheel follows the outer rail and the trailing wheel follows the inner rail so the centre pin of the bogie (and hence the vehicle) follows a path, which is the average of the outer and inner rails.