



Australian Government

Australian Transport Safety Bureau



ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Rail Occurrence Investigation No. 2005/002
Final

Derailment of
Pacific National Train 6MP4
Koolyanobbing, Western Australia
and
Pacific National Train 6SP5
Booraan, Western Australia

30 January 2005



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Abstract

At 1500 on 30 January 2005, Pacific National freight train 6MP4 derailed at Koolyanobbing, approximately 200 kilometres west of Kalgoorlie, Western Australia. Freight train 6MP4 consisted of two locomotives leading 48 freight wagons, was 4108 tonnes in total train weight and 1685 metres in length. A total of 23 wagons (a train length of 803 metres) derailed, with the main wreckage located over a turn-out and a road level crossing.

On the same day at 1605, Pacific National freight train 6SP5 derailed near Booraan, approximately 360 kilometres west of Kalgoorlie. Freight train 6SP5 consisted of two locomotives leading 46 freight wagons, was 3739 tonnes in total train weight and 1740 metres in length. A total of 19 wagons (a train length of 605 metres) derailed, with the main wreckage located to the east of a road level crossing.

Both freight trains had been travelling to Perth on the Defined Interstate Rail Network (DIRN), 6MP4 having started its journey in Melbourne and 6SP5 in Sydney. Both derailments occurred on a very hot day on the section of DIRN managed by WestNet Rail.

No serious injuries were sustained due to either derailment.

The investigation determined that the most probable cause for each derailment was track misalignments in the form of track buckles on a very hot day. The investigation also determined that a number of factors combined to contribute to each derailment.

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 the 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).

EXECUTIVE SUMMARY

At 1500 on Sunday 30 January 2005, Pacific National freight train 6MP4 derailed at Koolyanobbing. The derailment occurred at the 455.66 km point¹, approximately 200 kilometres west of Kalgoorlie, Western Australia. Freight train 6MP4 consisted of two locomotives leading 48 freight wagons (nine of which were 5-unit wagons). The train length was 1685 metres for a total train weight of 4108 tonnes.

On the same day at 1605, Pacific National freight train 6SP5 derailed near Booraan. This derailment occurred at the 292.16 km point, approximately 360 kilometres west of Kalgoorlie. Freight train 6SP5 consisted of two locomotives leading 46 freight wagons (13 of which were 5-unit wagons). The train length was 1740 metres for a total train weight of 3739 tonnes.

Both freight trains had been travelling to Perth on the Defined Interstate Rail Network (DIRN), 6MP4 having started its journey in Melbourne and 6SP5 in Sydney. Both derailments occurred on the section of DIRN managed by WestNet Rail. The temperature at the times was very hot.

No serious injuries were sustained due to either derailment. However, both derailments occurred in the vicinity of rural road level crossings.

Koolyanobbing

Freight train 6MP4 had negotiated a left hand curve (rated for 110 km/h) leading immediately into a turn-out. The turn-out provides the eastern access to a 2215 metre long, standard gauge crossing loop and siding at Koolyanobbing. Access to the crossing loop is via the right hand turn-out; however, the straight ahead main line route had been selected over the facing points for train 6MP4. A road level crossing over the main line, crossing loop and the siding is located approximately 140 metres past the turn-out.

As train 6MP4 traversed the turn-out, freight wagons began to derail. Freight train 6MP4 parted between the sixth and seventh wagon, a point 230 metres behind the lead locomotive cab. The brakes on the remaining wagons applied automatically due to loss of brake air pressure. The slight downhill gradient and the train's momentum prevented the wagons from stopping before colliding with the wagons that had derailed in front. A total of 23 wagons (a train length of 803 metres) derailed, with the main wreckage of 22 wagons located over the turn-out and the road level crossing. The two locomotives and six wagons stopped 1360 metres past the turn-out, with the sixth wagon derailed at the rear bogie.

The investigation determined that the most probable cause for the derailment of freight train 6MP4 at Koolyanobbing was track misalignment on a very hot day in the form of a buckle located within the turn-out, exacerbated by the passage of locomotives and rolling stock.

The investigation determined that a number of factors combined to contribute to the derailment of freight train 6MP4 at Koolyanobbing, any one of which may not have resulted in a derailment in its own right.

¹ Track kilometres measured from Perth

- It is likely that the timber sleepers replaced ten days before the derailment of 6MP4, exhibited a reduced friction bond with the ballast due to a lower degree of particle penetration. While rail traffic may have increased ballast consolidation, it is unlikely that maximum lateral resistance would have been achieved.
- It is likely that a reduced friction bond due to replacement sleepers, compounded by track tamping on the morning of the derailment, contributed to reduced resistance against lateral movement.
- Compressive longitudinal forces existed within the rail due to a recorded rail temperature approximately 18°C higher than the design neutral temperature of 40°C.
- It is likely that the lateral forces exerted by the passage of freight train 6SP5, approximately 75 minutes before the derailment of 6MP4, further reduced the track's resistance to lateral movement. If the track structure weakened sufficiently to allow lateral movement, it is likely that a misalignment would have developed under train 6SP5. However, the misalignment would not have been of sufficient magnitude to derail train 6SP5, and was unlikely to have been detectable by the driver of 6SP5.
- Initially the misalignment was not of sufficient magnitude to immediately derail 6MP4, allowing approximately 200 metres of train to traverse the misalignment. However, the misalignment caused severe lateral movement of the rail vehicles which further increased the misalignment until wagons ultimately derailed.

Booraan

Freight train 6SP5 had negotiated a left hand curve (rated for 110 km/h) leading into a straight section of track with a road level crossing located 365 metres west of the curve. As train 6SP5 approached the road level crossing, freight wagons began to derail. Freight train 6SP5 parted between the eleventh and twelfth wagon, a point 588 metres behind the lead locomotive cab. The brakes on the remaining wagons applied automatically due to loss of brake air pressure. The slight downhill gradient and the train's momentum prevented following wagons from stopping before colliding with the wagons that had derailed in front.

A total of 19 wagons (a train length of 605 metres) derailed, with the main wreckage of 17 wagons located to the east of the road level crossing. The two locomotives and 11 wagons stopped 1080 metres past the road level crossing, with the tenth wagon derailed at the rear bogie. The eleventh wagon (a 5-unit container wagon) was still connected to the tenth wagon. However, it was completely derailed with five of its six bogies separated from the wagon and remaining in the main wreckage.

The investigation determined that the most probable cause for the derailment of freight train 6SP5 at Booraan was a track misalignment on a very hot day in the form of a buckle, exacerbated by the passage of locomotives and rolling stock.

The investigation determined that a number of factors contributed to the derailment of freight train 6SP5 at Booraan, any one of which may not have resulted in a derailment in its own right.

- Even though the track structure design at Booraan may be resistant to longitudinal rail movement, longitudinal rail movement may have occurred over a period of time.

- The level crossing and slight descending gradient had the potential to create a bunching effect in the track immediately before the level crossing, lowering the effective neutral temperature. The lower neutral temperature increased the influence of thermal expansion such that the forces applied to the track structure also increased.
- Compressive longitudinal forces existed within the rail due to a recorded rail temperature approximately 21°C higher than the design neutral temperature of 40°C.
- It is likely that the lateral forces exerted by the passage of freight train 1PS6, approximately two hours before the derailment of 6SP5, further reduced the track's resistance to lateral movement. If the track structure weakened sufficiently to allow lateral movement, it is likely that a misalignment would have developed under train 1PS6. However, the misalignment would not have been of sufficient magnitude to derail train 1PS6, and was unlikely to have been detectable by the driver of 1PS6.
- Initially the misalignment was not of sufficient magnitude to immediately derail 6SP5, allowing approximately 600 metres of train to traverse the misalignment. However, the misalignment progressively increased lateral movement of rail vehicles, further increasing the misalignment until wagons ultimately derailed.

Analysis related to both derailments

Considering how unusual it is for two similar derailments to occur approximately an hour apart and within 200 kilometres of each other, extensive examination and analysis of freight loading, train handling, and rollingstock was also conducted. There was no evidence or indication of any fault, defect or deficiency in freight loading, train handling, or rollingstock that may have directly contributed to one or both derailments. Similarly there was no evidence or indication of any fault, defect or deficiency in freight loading, train handling, or rollingstock that may have contributed to the development of a track defect subsequently causing one or both derailments.

Recommendations

As a result of its investigation into the derailment of freight train 6MP4 at Koolyanobbing and freight train 6SP5 at Booraan, the ATSB makes a number of recommendations, relating to:

- procedures for managing reduced track stability due to track maintenance
- procedures for monitoring and management of longitudinal rail movement on the defined interstate rail network
- procedures for assessing minor defects and identifying factors that may have contributed to the defect
- documenting procedures for managing safe operations during periods of high ambient temperature
- implementation and monitoring of safety actions.

1

INTRODUCTION

At 1500 on Sunday 30 January 2005, Pacific National freight train 6MP4 derailed at Koolyanobbing. The derailment occurred at the 455.66 km point², approximately 200 kilometres west of Kalgoorlie, Western Australia. Freight train 6MP4 consisted of two locomotives leading 48 freight wagons (nine of which were 5-unit wagons). The train length was 1685 metres for a total train weight of 4108 tonnes.

A total of 23 wagons were derailed (four of which were 5-unit wagons), with the majority of derailed rollingstock and damaged civil infrastructure extending over a 205 metres section of track. Derailed rollingstock also extended over a rural road level crossing, considerably increasing the risk of injury, especially considering the road provided access to local mining operations.

On the same day at 1605, Pacific National freight train 6SP5 derailed near Booraan. This derailment occurred at the 292.16 km point, approximately 360 kilometres west of Kalgoorlie. Freight train 6SP5 consisted of two locomotives leading 46 freight wagons (13 of which were 5-unit wagons). The train length was 1740 metres for a total train weight of 3739 tonnes.

A total of 19 platforms and wagons were derailed (four of which were 5-unit wagons), with the majority of derailed rollingstock and damaged civil infrastructure extending over approximately 175 metres.

Both freight trains had been travelling to Perth on the Defined Interstate Rail Network (DIRN), 6MP4 having started its journey in Melbourne and 6SP5 in Sydney. Both derailments occurred on the section of DIRN managed by WestNet Rail. The track at these locations consists of continuously welded rail secured to concrete sleepers by resilient fasteners and supported on ballast. The configuration is typical of the standard used for the DIRN in Western Australia.

Figure 1: Derailed wagons at Koolyanobbing (left) and Booraan (right)



Booraan photo (right) by WestNet Rail

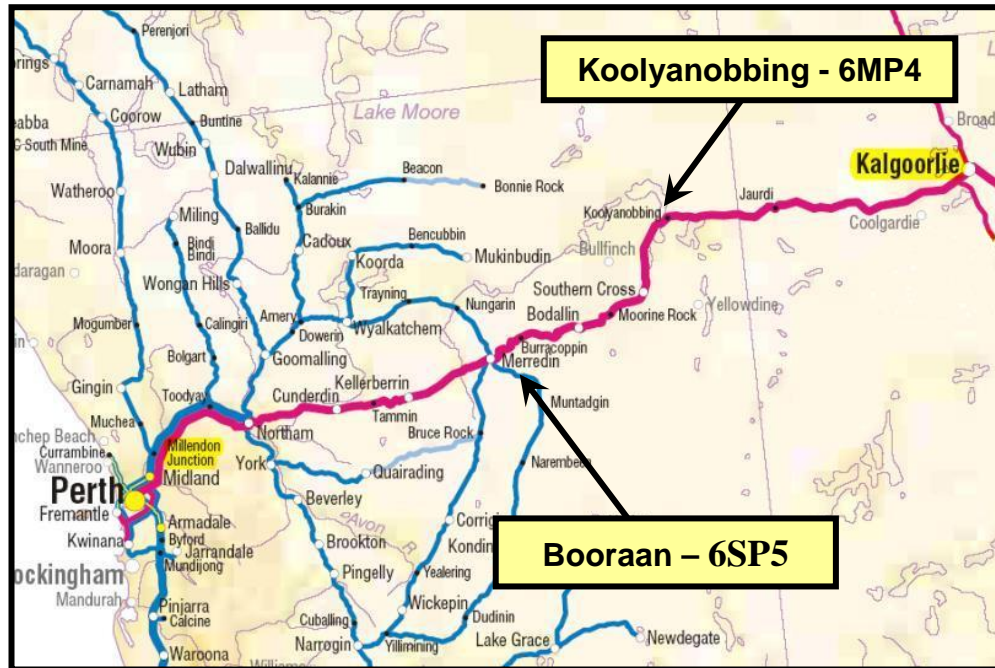
² Track kilometres measured from Perth

WestNet Rail provides line-side signalling at the crossing loops, controlled remotely from a Centralised Train Control (CTC) centre located at Merredin. Voice communication between trains and train control is by UHF radio.

Due to the magnitude of these derailments, and the unusual occurrence of two derailments in close proximity and time, the Australian Transport Safety Bureau (ATSB) initiated an independent investigation into both accidents.

2.1 The Occurrence and Location

Figure 2: Location of derailments



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Koolyanobbing

The derailment at Koolyanobbing occurred at the 455.66 km point, approximately 200 kilometres west of Kalgoorlie. Freight train 6MP4, travelling at 107 km/h, had negotiated a left hand curve (rated for 110 km/h) leading immediately into a turn-out. The turn-out provides the eastern access to a 2215 metres standard gauge crossing loop and siding at Koolyanobbing. Access to the crossing loop is via the right hand turn-out; however, the straight ahead main line route had been selected over the facing points for train 6MP4.

The track at Koolyanobbing is predominantly continuously welded rail secured to concrete sleepers by resilient fasteners and supported on ballast, but the turn-out is supported on timber sleepers.

Koolyanobbing crossing loop and siding is relatively remote from populated areas; however, a rural road level crossing which provides access to local ore mining operations is located approximately 140 metres beyond the turn-out. WestNet Rail provides line-side signalling at the Koolyanobbing crossing loop and siding, controlled remotely from a Centralised Train Control (CTC) centre located at Merredin.

As train 6MP4 traversed the turn-out, freight wagons began to derail. Freight train 6MP4 parted between the sixth (RQJW22060) and seventh (RQFY00031) wagon, a point 230 metres behind the lead locomotive cab. The brakes on the remaining

wagons applied automatically due to loss of brake air pressure but the slight downhill gradient and the train's momentum resulted in the following 21 wagons colliding and jack-knifing into the seventh wagon and the increasing number of derailed rollingstock.

A total of 23 wagons (803 metres) derailed, with the main wreckage of 22 wagons located over the turn-out and the road level crossing. The two locomotives and six wagons stopped 1360 metres past the turn-out, with the sixth wagon derailed at the rear bogie.

Booraan

The derailment at Booraan occurred at the 292.16 km point, approximately 360 kilometres west of Kalgoorlie. This location was four kilometres into a section of standard gauge track between Booraan crossing loop and Merredin. Freight train 6SP5, travelling at 97 km/h, had negotiated a left hand curve (rated for 110 km/h) leading into a straight section of track.

The derailment occurred in a relatively remote section between Booraan and Merredin crossing loops; however, a rural road level crossing was located approximately 365 metres beyond the curve tangent point.

As train 6SP5 approached the road level crossing, freight wagons began to derail. Freight train 6SP5 parted between wagon 11 (RRAY07175) and wagon 12 (RQNW60034), a point 588 metres behind the lead locomotive cab. As at Koolyanobbing, the brakes on the remaining wagons applied automatically due to loss of brake air pressure. The slight downhill gradient and the train's momentum resulted in 16 wagons jack-knifing into wagon 12 and the increasing number of derailed rollingstock.

A total of 19 wagons (605 metres) derailed, with the main wreckage of 17 wagons located to the east of the road level crossing. The two locomotives and 11 wagons stopped 1080 metres past the road level crossing, with the tenth wagon derailed at the rear bogie. The eleventh wagon (a 5-unit container wagon) was still connected to the tenth wagon; however, it was completely derailed with five of its six bogies separated from the wagon and remaining in the main wreckage.

2.2 Organisations

WestNet Rail

WestNet Rail is an accredited rail organisation that has responsibility for the management of approximately 660 route kilometres of standard gauge interstate track in Western Australia.

As the track infrastructure manager, WestNet Rail is responsible for the maintenance of this infrastructure and has contracted the undertaking to John Holland Rail Pty Ltd.

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 trains 6MP4 and 6SP5.

2.3 Personnel Involved

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

- two Pacific National locomotive drivers crewing train 6MP4 and three Pacific National locomotive drivers crewing train 6SP5
- WestNet Rail train control staff authorising the passage of trains towards Perth.

Consistent with Pacific National procedures, all drivers were requested to undertake a breath test following the accident. The tests returned a 'negative result' for all drivers.

The investigation determined that fatigue or medical factors did not contribute either directly or indirectly to either derailment. However, further analysis of individual actions was conducted to determine any inconsistencies that may have contributed to the derailments.

2.4 Injuries

No serious injuries were sustained due to the derailments of 6MP4 and Koolyanobbing and 6SP5 at Booraan. However, some minor bumps and bruising was reported by the locomotive drivers with one requiring further treatment for soft tissue injuries.

While no person was seriously injured had the locomotives derailed, the risk of injury to the locomotive drivers would have increased. It should also be recognised that both derailments occurred in the vicinity of rural road level crossings. Had road vehicles been at the level crossing at the time of the derailment, the risk of serious or fatal injury would have increased significantly.

Figure 3: View of the level crossing at Koolyanobbing



2.5 Damage

Pacific National

Combining the two derailments, approximately 2200 tonnes of freight and a total of 42 wagons (eight of which were 5-unit wagons) were derailed, equating to approximately 1408 metres of train. A significant proportion of the rollingstock (wagon bodies, bogies and wheel-sets) were expected to be beyond repair. Similarly, a significant proportion of the freight was not salvageable.

WestNet Rail

At Koolyanobbing, 290 metres of standard gauge track, the turnout and the catch points at the siding required replacement. The road level crossing across three tracks required rebuilding with the replacement of three trackside signals, two flashing light assemblies and the associated trackside equipment enclosure.

At Booraan, 760 metres of standard gauge track required replacement. A temporary 260 metre deviation with a speed restricted to 15 km/hr was constructed to facilitate a prompt resumption of train services. The road level crossing required rebuilding including the replacement of two flashing light assemblies.

Rail services between Merredin and Kalgoorlie resumed on 3 February 2005, four days after the derailments at Koolyanobbing and Booraan. However, restoration of the main line and removal of the deviation at Booraan was not completed until 26 August 2005, after which normal track speeds were reinstated.

2.6 Dangerous Goods

Both freight trains were transporting dangerous goods, some of which were loaded on wagons derailed during the accidents. Consequently, there was release or spillage of dangerous goods at both derailment sites.

At both Koolyanobbing and Booraan, access was restricted until emergency services had assessed the derailment sites. Only after receiving clearance from emergency services, and advice on managing the release of dangerous goods, was access permitted to start derailment assessment and a controlled recovery processes.

2.7 Environmental Conditions

Environmental conditions were considered to be a contributing factor to both derailments and are discussed further throughout the analysis section of this report. Information on the weather conditions at both locations was obtained from the Bureau of Meteorology (BoM).

Koolyanobbing

The weather in the vicinity³ of Koolyanobbing was very hot with a moderate NW breeze (20 km/h) and no cloud cover. The recorded temperature at 1500 was 38.4°C; however, the daily maximum reached 39.6°C. The sun was to the west at an elevation of approximately 51°.

Booraan

The weather in the vicinity⁴ of Booraan was very hot with a light NW breeze (four km/h) and no cloud cover. The maximum recorded temperature was 39.8°C at 1500. The sun was to the west at an elevation of approximately 39°.

2.8 Civil Infrastructure

Some aspects of civil infrastructure design and maintenance were associated with contributing factors in both derailments and are discussed further throughout the analysis section of this report.

Koolyanobbing

The derailment at Koolyanobbing occurred over a set of facing points that provide trains with access to a crossing loop via a right hand turn-out. Immediately east of the turn-out is a 1200 metre radius curve, through which freight trains with 21 tonne axle loads are rated for a track speed of 110 km/hr. The track has a descending grade of 1 in 236 until 200 metres before the turn-out, at which point the gradient reduces to 1 in 653.

³ Recorded at Southern Cross, 48 kilometres from Koolyanobbing

⁴ Recorded at Merredin, eight kilometres from Booraan

A 200 metres section of track, including the turn-out, consists of continuously welded rail weighing 47 kg/m, supported on ballasted timber sleepers at approximately 600mm spacing. The rail is secured to sleeper plates using resilient clips, which in turn are secured to the sleeper using lock-spikes.

The track structure either side of the timber-sleepered section consists of continuously welded rail weighing 47 kg/m supported on ballasted concrete sleepers at approximately 660 mm spacing and secured using resilient clips.

In general, the track structure was considered to be in good condition with the ballast profile considered full for both shoulder and crib⁵.

Booraan

The derailment at Booraan occurred over a straight section of track, a short distance after a 1200 metre radius curve. The track has a descending grade of 1 in 601 through the curve before increasing to 1 in 150 at the tangent point. The track speed is 110km/hr for freight trains with 21 tonne axle loads.

The track structure at Booraan consists of continuously welded rail weighing 60 kg/m supported on ballasted concrete sleepers at approximately 660 mm spacing and secured using resilient clips.

In general, the track structure was considered to be in good condition with the ballast crib considered full. However the ballast profile did not demonstrate a full shoulder width in all areas. Ballast profile issues are discussed further throughout the analysis section.

2.9 Rollingstock

Aspects of rollingstock design and maintenance are discussed further throughout the analysis section of this report.

Train 6MP4 (Koolyanobbing)

Pacific National train 6MP4 originated at the Melbourne Freight Terminal and was travelling to Perth via Adelaide. The train consisted of two NR class diesel electric locomotives, followed by 48 freight wagons (nine of which were 5-unit wagons). The train length was 1685 metres for a total train weight of 4108 tonnes.

Of the 23 wagons that derailed, three were identified to be of interest and quarantined for further examination.

Train 6SP5 (Booraan)

Pacific National train 6SP5 originated at the Sydney Freight Terminal and was travelling to Perth via Broken Hill. The train consisted of two NR class diesel

⁵ The terms used to describe ballast profile are:
Shoulder – denoting the ballast profile present at the ends of a sleeper, and
Crib – denoting the ballast profile between two adjacent sleepers.
A full shoulder and crib is indicated when ballast's surface is level with the top surface of each adjacent sleeper and has the required width of ballast at the ends of each sleeper

electric locomotives, followed by 46 freight wagons (13 of which were 5-unit wagons). The train length was 1740 metres for a total train weight of 3739 tonnes.

Of the 19 wagons that derailed, three were identified to be of interest and quarantined for further examination.

2.10 Signalling and Communication

The investigation determined that WestNet Rail's signalling and communication systems had operated correctly and did not contribute either directly or indirectly to either derailment. Similarly, the communication systems operated correctly immediately following the accident and throughout the post accident response and recovery.

3.1 Mechanism of Derailment

The investigation team committed significant resources to analysis of derailment mechanisms. Derailments generally occur due to:

- deficiencies in track structure
- deficiencies in rollingstock
- inappropriate train handling
- inappropriate freight loading; or
- a combination of these factors.

The initial reports for both derailments indicated that the trains had encountered track misalignments while travelling at line speed. It is unusual for two similar derailments to occur approximately an hour apart and within 200 kilometres of each other. This raised speculation that the two accidents may have been closely related, and that freight loading, train handling, or a rollingstock defect may have contributed to the development of a track defect subsequently causing one or both derailments. However, this did not preclude the possibility that the two derailments were unrelated.

This investigation report presents analysis and findings primarily related to the most likely cause of derailment. However, considering the unusual occurrence of two similar derailments, analysis and discussion has been included in Section 3.6 regarding possible alternative derailment mechanisms.

3.1.1 Site Evidence

Koolyanobbing

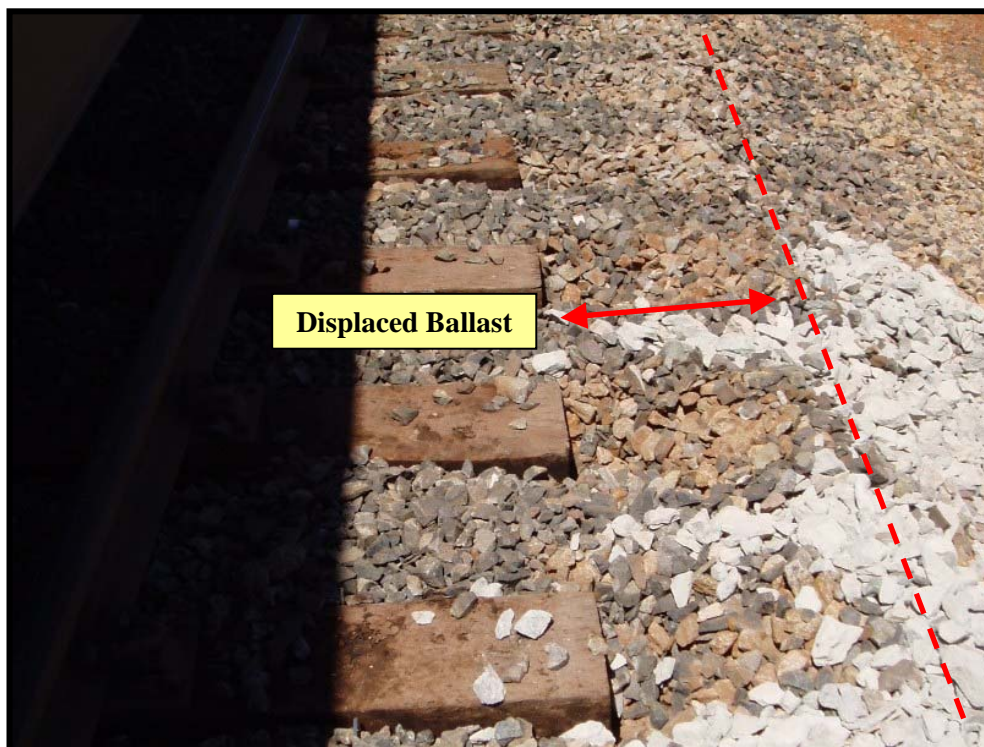
The derailment at Koolyanobbing occurred over a set of facing points that provide trains with access to a crossing loop via a right hand turn-out. Freight train 6MP4 had negotiated a left hand curve that leads immediately into the turn-out, which was set for the main line. The curve, rated at main line speed, has a slight downhill gradient. As the train exits the curve the track levels out before beginning a slight rise. A road level crossing is located approximately 160 metres beyond the curve tangent point.

Track curvature with trees and bushes at the side of the track limited the locomotive driver's visibility of the rails ahead to approximately 300 metres. The turn-out is immediately beyond the tangent point of the curve; therefore the driver's first view of the turnout would have been at approximately 300 metres. However it would be unlikely that a driver could see any track misalignment at this distance. It was calculated that a train would have to be approximately 85 metres from the curve tangent point before it would be possible for a driver to see along the straight track and detect any misalignment.

Displaced ballast was observed at the ends of some sleepers through the turn-out. While this may indicate that a track misalignment existed before the passage of

6MP4, it could also have occurred as a result of the derailment. Beyond this point, there was significant damage to the track structure. There was no sleeper or rail damage observed throughout the curve before the derailment site.

Figure 4: Displaced ballast at ends of sleepers at Koolyanobbing



Booraan

The derailment at Booraan occurred over a straight section of track, a short distance after a left hand curve rated for main line speed. The track leading up to the derailment site has a slight downhill gradient with a road level crossing located approximately 365 metres beyond the curve tangent point.

Similar to the Koolyanobbing site, the driver's view ahead was limited to about 350 metres by the curvature of the track and adjacent trees and bushes. It was calculated that a train would have to be approximately 85 metres from the curve tangent point before it would be possible for a driver to see along the straight track and detect any misalignment.

The Booraan site was also similar to Koolyanobbing in that displaced ballast was observed at the ends of some sleepers at the eastern approach to the derailment site, with damage to the track structure to the west of this point only. There was no sleeper or rail damage observed throughout the curve before the derailment site.

Figure 5: Displaced ballast at ends of sleepers at Booraan

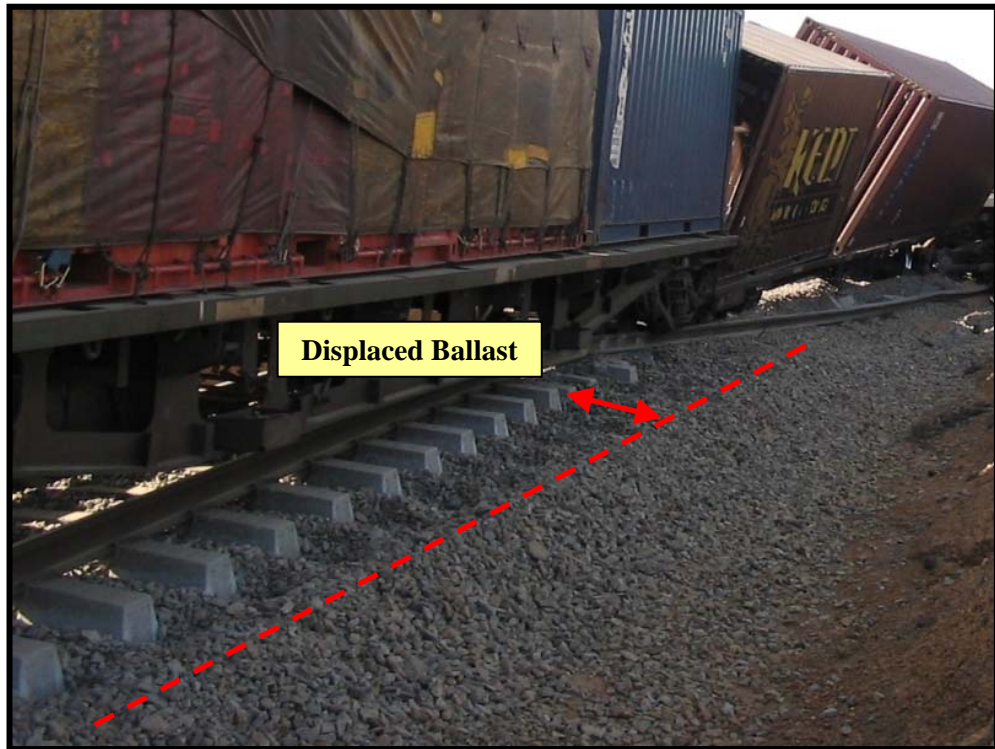


Photo by WestNet Rail

3.1.2 Driver Actions and Voice Communication

Koolyanobbing

Two drivers crewed freight train 6MP4. They started their driving shift at Parkeston with train 6MP4 departing the yard at approximately 1200.

The drivers told the investigation that when they started their shift the day was already very hot and how they expected that 'Heat Speed Restrictions' (HSR) would already be in force, especially over the sections of track supported on timber sleepers. The drivers sought confirmation from train control who advised that HSR were not in force; however, the drivers chose to exercise their prerogative and travel over the timber-sleepered sections at a reduced speed. At approx 1415 train control contacted the driver of train 6MP4 to advise that HSR of 80 km/h were now in force over the timber-sleepered sections of track. The driver confirmed that they had restricted their travelling speed to 70 km/h over the sections of track supported on timber sleepers.

The sections of track supported on timber sleepers ended approximately 30 kilometres east of Koolyanobbing, after which the track was supported on concrete sleepers. Since HSR were not in force over the concrete sections, the drivers advised the investigation that they gradually increased speed and were travelling at approximately 108 km/h⁶ immediately approaching Koolyanobbing.

⁶ Note that the locomotive data log recorded a speed of 107 km/h

The drivers stated that surrounding bushes on the curve immediately east of the Koolyanobbing crossing loop limited visibility until the locomotive was approximately 70 – 100 metres from the turnout. When approaching the turn-out from the east, the track transitions from a slight descending gradient to an ascending gradient requiring a gradual increase in locomotive power. Upon sighting the turnout, the drivers saw a significant misalignment, in the form of a sharp track kick to the left (south) within the turnout. There was not sufficient time to apply braking before the locomotive traversed the misalignment.

The drivers told the investigation that the misalignment resulted in such severe motion that they were certain the locomotive would derail. While the driver in charge was thrown against the centre console then back onto the seat, the second driver was thrown against the window then onto the floor of the locomotive. The driver in charge immediately began a brake application and advised that the locomotive and the remaining railed wagons stopped an estimated 800 – 900 metres beyond the misalignment. The driver in charge then contacted train control and reported that 6MP4 had derailed at the Koolyanobbing crossing loop.

Booraan

There were three PN personnel on train 6SP5: two drivers and a third crew member travelling on an orientation trip. They started their driving shift at Parkeston with train 6SP5 departing the yard at approximately 1015.

The drivers stated that when they started their shift the day was already very hot and expressed surprise that an HSR had not been in place, particularly over timber sleepers. The drivers sought confirmation from train control who advised that HSR were not in force until 1400, at which time HSR would apply on the timber-sleepered sections.

The drivers said that generally the trip was uneventful until approximately 1500 when radio communication alerted them to the derailment of 6MP4 at Koolyanobbing. Considering their own concerns regarding the very hot weather and the possibility that 6MP4 had encountered a heat related misalignment, the drivers reduced their speed to 10 km/h below the posted line speed.

As the lead locomotive exited the curve leading to Booraan, the drivers observed a misalignment in the form of a sharp track kick to the left (east). The drivers estimated that their initial sighting was approximately 140 metres before the misalignment, providing sufficient time to make a brake application before traversing the misalignment. The drivers told the investigation that braking was beginning to take effect as the locomotives reached the misalignment.

While the lateral motion of the locomotives was significant, it was not overly severe, with the drivers expressing some hope that they may have been able to ride through the misalignment. However, in the lead locomotive's side mirrors the crew saw the rocking motion of following wagons progressively increase until wagons began to derail. When the brake air pressure was lost, indicating that the train had parted, the driver applied emergency braking to stop the locomotive and the remaining railed wagons. The driver then contacted train control and reported that 6SP5 had derailed.

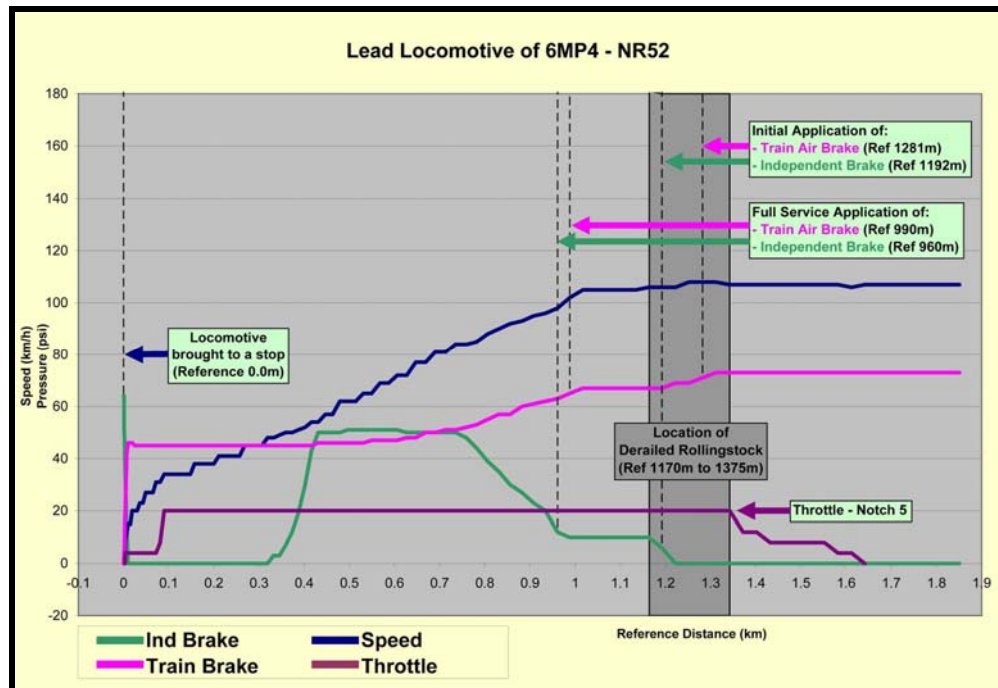
3.1.3 Locomotive Data Log

Koolyanobbing

Before Koolyanobbing, 6MP4 was travelling at approximately 107 km/h down a slight gradient with the locomotive controls at idle as it entered the curve leading up to the turn-out. Approximately 270 metres before the turn-out, the driver of 6MP4 began to apply a gradual increase in locomotive power to ensure that a constant speed could be maintained.

The driver of 6MP4 had only just achieved throttle notch five as the locomotives approached the turn-out. Within two seconds the driver made an initial 50kPa brake pipe reduction (train brake) and allowed the independent (locomotive) brake to apply automatically. Full service application of the train brake was made approximately 10 seconds after the initial application and the independent brake was allowed to fully apply.

Figure 6: Graphical representation of NR52 locomotive data log (Lead locomotive of 6MP4)

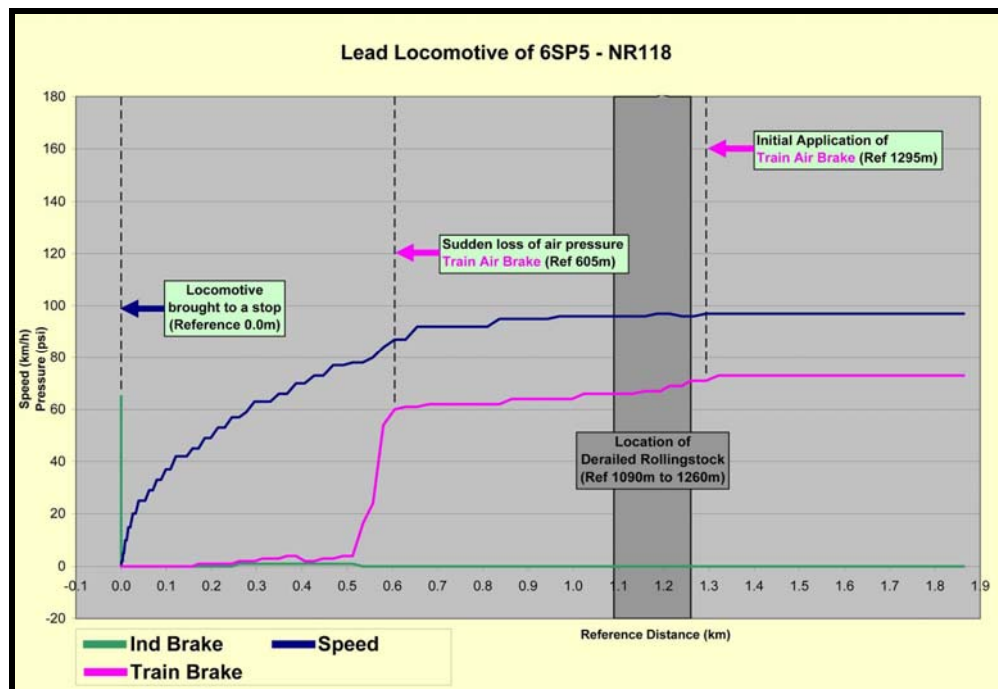


Although the independent brake was allowed to automatically apply, the retention of throttle notch five and gradual reduction of brake pipe pressure indicates that the driver was endeavouring to keep the train from bunching. Approximately 1000 metres past the turn-out, the driver released the locomotives' independent brake before reducing the throttle and bringing the train to a stop at a point 1300 metres after the initial brake application. These actions are consistent with an attempt to prevent derailed wagons colliding with the locomotives due to the locomotives' greater braking force when compared to wagons, either loaded or empty.

Booraan

East of the Booraan derailment site 6SP5 was travelling at approximately 97km/h down a slight gradient with the locomotive controls at idle. Approximately 150 metres after exiting the curve, the driver of 6SP5 made an initial application of the train's air brakes. The driver continued to increase the braking effort in gradual increments for approximately 700 metres after the initial application until a sudden loss in brake line pressure indicated that the brake line and, most likely, the train had parted. The front section of the train stopped 1300 metres after the initial brake application.

Figure 7: Graphical representation of NR118 locomotive data log (Lead locomotive of 6SP5)



3.1.4 Summary of Mechanism of Derailment

The drivers of both 6MP4 at Koolyanobbing and 6SP5 at Booraan reported sighting a distinct rail buckle and experienced a rough ride as they passed over the area. The drivers' statements are supported by the evidence from the data logger of both locomotives.

Koolyanobbing

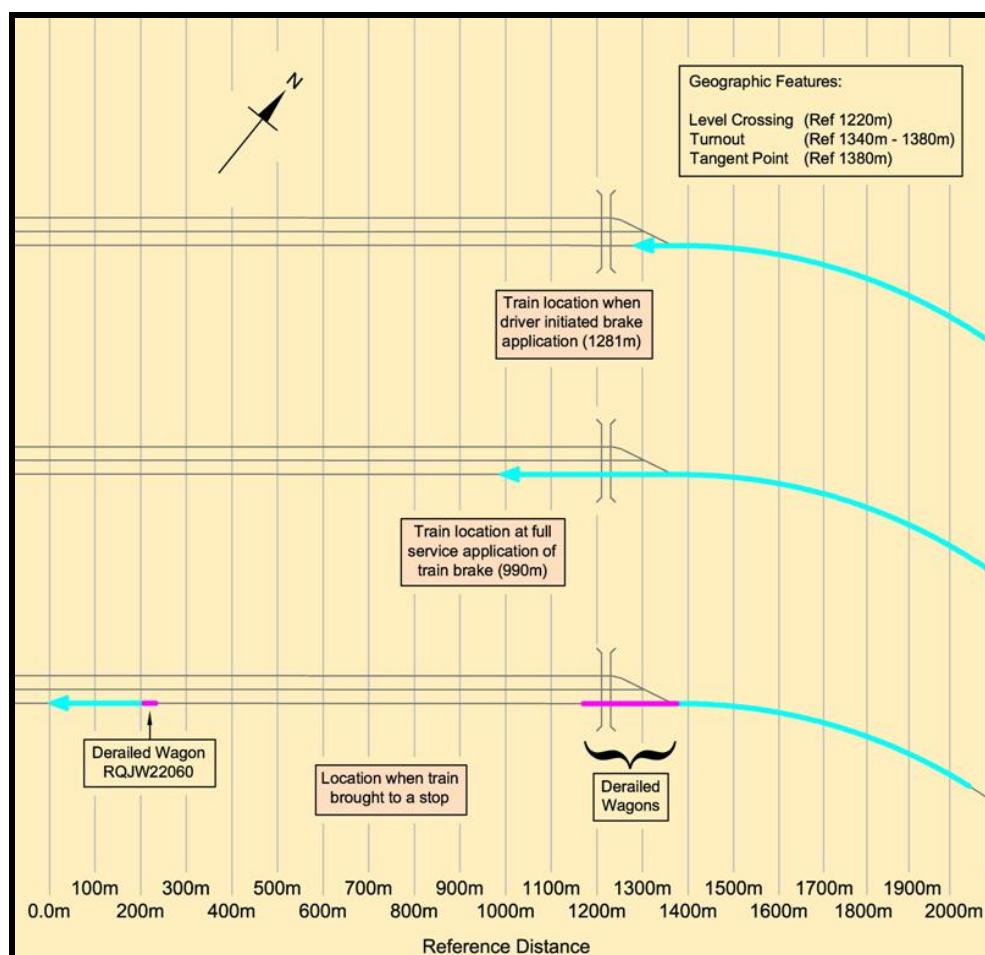
The majority of derailed rollingstock and damaged civil infrastructure extended for 205 metres, beginning at the turn-out. Displaced ballast at the ends of some sleepers through the turn-out suggests that the track had shifted laterally. No sleeper or rail damage was observed east of this location at Koolyanobbing.

Based on a hypothesis that a misalignment existed in the turn-out, the earliest that a driver could first detect it is approximately 85 metres before the curve tangent point. This is 120 metres east of the estimated location of the misalignment. At 107km/h, this equates to four seconds between sighting the misalignment and

traversing the misalignment. However, not expecting any problem through the turn-out, it is likely that the driver's attention would be towards the level crossing to ensure it was clear of road traffic. For this reason, it is likely that the driver would not have reacted to a misalignment at the turn-out until the lead locomotive was almost at the turn-out. The locomotive data log supports this in that the application of braking occurs approximately 60 metres (two seconds at 107km/h) beyond the estimated location of the misalignment.

The first wagon to derail was approximately 200 metres behind the lead locomotive. If the cause of the derailment was a defective wagon, then the behaviour of the wagon could possibly have alerted the driver to a potential rollingstock fault, which would prompt the driver to take some action. Had this been the case, it would be reasonable to expect evidence of track damage approximately 200 metres east of the point at which brake application occurred. However, analysis of the locomotive data log indicated that the driver first applied braking as the locomotive traversed the derailment site. When the locomotive brake was applied, the wagon that was the first to derail was apparently travelling normally as there was no track damage east of the derailment site.

Figure 8: Representation of 6MP4 as it progressed through the derailment site



When considering the physical site evidence and mapping it against the locomotive data log, it is unlikely that any observed rollingstock fault would have initiated the driver's actions. Similarly, the drivers reported actions are supported by both the locomotive data log and the physical site evidence.

Analysis of evidence suggests that the most probable cause for the derailment of 6MP4 at Koolyanobbing was a track misalignment within the turn-out.

Booraan

At Booraan the majority of derailed rollingstock from train 6SP5 and damaged civil infrastructure started at a location beginning 185 metres past the curve's tangent point. The majority of derailed rollingstock and damaged civil infrastructure extended for a further 175 metres. Displaced ballast at the ends of some sleepers at the approach side of the derailment site suggests that the track had shifted laterally at this point. No sleeper or rail damage was observed east of this location at Booraan.

Again, as with Koolyanobbing, the probability is that rollingstock did not initiate the derailment. The main evidence for this rests with the timing of the brake application. The first wagon to derail was approximately 580 metres behind the lead locomotive cab. The locomotive data log indicates that the driver had initiated the brake application at least 35 metres before any damaged track, placing this wagon 615 metres from the first indication of damaged track.

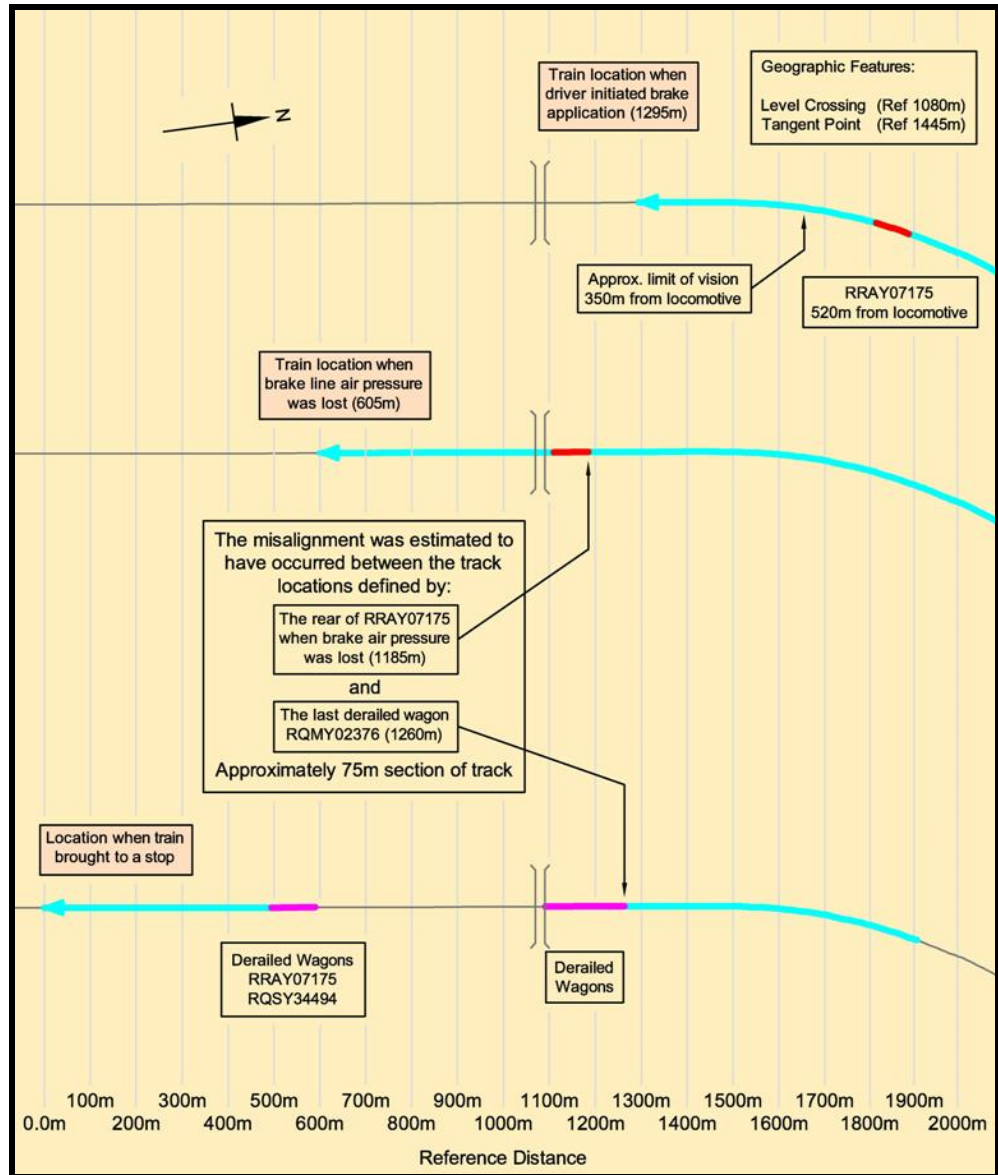
Given the limited view of the track ahead because of track curvature and trackside trees and bushes, a locomotive driver's visibility of the following wagons is limited to approximately 350 metres. The first wagon to derail would not have been visible as it would have been on the curve and obscured by trees and bushes.

Approximately 150 metres after exiting the curve the driver of 6SP5 made an initial application of the train's air brakes. The driver continued to increase the braking effort in gradual increments for approximately 700 metres after the initial application until 25 seconds later a sudden loss in brake line pressure indicated that the brake line and, most likely, the train had parted. The braking technique implemented by the driver aimed to keep the train 'stretched' while gradually slowing the train in a controlled manner. This technique transfers the minimum level of lateral force to the track and is consistent with an attempt to ride a train through a track misalignment.

As with Koolyanobbing, physical site evidence mapped against the locomotive data log indicates that the driver's actions are unlikely to have been initiated by any observed rollingstock fault. Similarly, the driver's reported actions are supported by both the locomotive data log and the physical site evidence.

It is reasonable to assume that the uncontrolled loss of brake pressure occurred due to the separation of the train between the 13th and 14th wagons. From the locomotive data log, it is possible to position this point 67 metres from the first damaged sleeper. It is likely that any track condition prompting an action from the driver would be located between the first damaged sleeper and the point at which wagons became sufficiently unstable to result in a train separation.

Figure 9: Representation of 6SP5 as it progressed through the derailment site



Analysis of evidence suggests that the most probable cause for the derailment of 6SP5 at Booraan was a track misalignment located within a 75 metre section of track beginning approximately 185 metres past the curve’s tangent point.

3.2 Track Misalignment and Stability

Continuous welded rail (CWR) provides significant advantages in economics, maintenance and ride comfort. However, CWR needs to be appropriately managed. The high longitudinal rail forces that occur within CWR during extremely hot weather can result in misalignment if the track is not maintained in good condition.

Track misalignment will generally take one of two forms: a track shift where lateral alignment defects gradually appear over time; or a track buckle where a large lateral deflection may occur quite suddenly. As previously described, the most probable cause for both derailments was a track misalignment in the form of a buckle.

Therefore, analysis was focused primarily on factors that could contribute to this form of track misalignment.

Track misalignment in CWR has been extensively studied in the railway industry. A track buckle generally occurs when the track structure cannot adequately constrain the vertical, lateral, and longitudinal forces exerted by the rail. The main factors influencing track buckling are:

- longitudinal rail forces
- track lateral resistance
- dynamic rail forces.

3.2.1 Longitudinal Rail Forces

Longitudinal rail force due to temperature is a primary factor contributing to track buckles. Thermal expansion will cause rail to lengthen as temperature rises and shorten as temperature decreases. CWR has no joints to accommodate changes in rail length; consequently, longitudinal forces develop within the rail.

The temperature, at which the rail is neither in tension or compression, is referred to as the neutral temperature. If the rail temperature is less than the neutral temperature the longitudinal force will be in tension, increasing the risk of a rail break. If the rail temperature is greater than the neutral temperature the longitudinal force will be in compression, increasing the risk of a track buckle.

For rail of constant cross section and metallurgical properties, the longitudinal rail force due to temperature is proportional to the difference between actual rail temperature and the rail neutral temperature. For this investigation, actual measurements were available for rail temperature at the Koolyanobbing and Booraan locations allowing for temperature difference to be quantified. Consequently, the following analysis expresses longitudinal rail forces in terms of rail temperature, temperature difference and shifts in rail neutral temperature.

Rail is installed or periodically adjusted such that the rail is neither in tension or compression at a specific temperature⁷. However, the neutral temperature of the rail can change over time. Extraordinarily high or low ambient air temperatures, track maintenance and dynamic rail vehicle forces can cause a redistribution of the longitudinal rail forces, effectively modifying the neutral temperature⁸. If the neutral temperature reduces, then the longitudinal rail forces at higher ambient temperatures can be larger, increasing the risk of a track buckle.

At high ambient temperatures, rail temperature can rise significantly with temperatures 20°C above ambient common in some locations⁹. If the track is not adequately constrained, large compressive force can cause the track to buckle in the lateral or in some cases the vertical plane. Curves, especially in the presence of

7 Referred to in this report as 'design neutral temperature'

8 Referred to in this report as 'effective neutral temperature'

9 Ambient temperature is not the only factor that influences rail temperature. A high ambient temperature on a windy day can result in a lower rail temperature than the same ambient temperature on a still day.

initial lateral alignment defects, tend to be more vulnerable to heat induced buckle than tangent track.

Koolyanobbing

Table 1: Temperature data for Koolyanobbing

Design neutral temperature	40°C
Maximum ambient temperature (BOM, Southern Cross)	39.6°C
Maximum ambient temperature (WestNet Rail, Koolyanobbing)	39.6°C
Maximum rail temperature (WestNet Rail, Koolyanobbing)	58.3°C

Note: A moderate breeze (20km/h) was recorded at Southern Cross at 1500.

The rail temperature at Koolyanobbing exceeded the design neutral temperature by approximately 18°C. It is unlikely that an 18°C temperature differential would itself result in sufficient longitudinal rail forces to cause ‘explosive’¹⁰ track buckling, however; any temperature differential above the effective neutral temperature would result in compressive longitudinal rail forces, consequently increasing the risk of a track misalignment.

Booraan

Table 2: Temperature data for Booraan

Design neutral temperature	40°C
Maximum ambient temperature (BOM, Merredin)	39.8°C
Maximum ambient temperature (WestNet Rail, West Merredin)	37.9°C
Maximum rail temperature (WestNet Rail, West Merredin)	61.3°C

Note: A light breeze (4km/h) was recorded at Merredin at 1500.

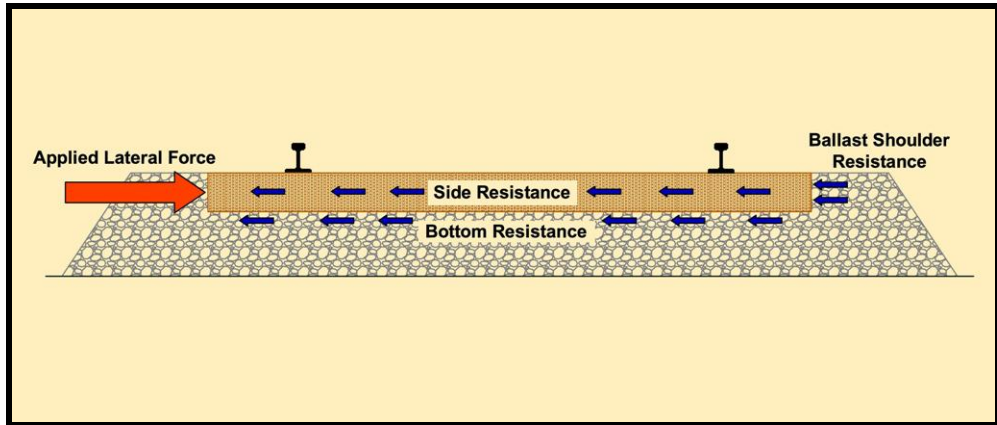
The temperature data was measured at Merredin, approximately eight kilometres from Booraan. It is reasonable to assume that the actual temperatures at Booraan would be consistent with those measured at Merredin. The measured rail temperature exceeded the design neutral temperature by approximately 21°C. Similar to Koolyanobbing, ‘explosive’ track buckling is unlikely; however, compressive longitudinal rail forces would increase the risk of a track misalignment.

3.2.2 Track Lateral Resistance

A track buckle in the vertical plane is uncommon and primarily prevented by the physical mass of the rail and the sleepers the rail is fastened to. The more common track buckle in the lateral plane is prevented by the lateral resistance of the track structure. Lateral restraint is dependent on each sleeper’s bottom friction, side friction and the end resistance provided by the ballast shoulder.

¹⁰ ‘Explosive’ track buckling describes buckling due to temperature induced forces only.

Figure 10: Lateral resistance factors



Bottom friction is primarily influenced by the ballast angularity and the sleeper type and weight, which in turn affects the friction developed at the sleeper's bottom-ballast interface. Side friction is primarily influenced by the ballast angularity and the compaction of ballast between each sleeper, which in turn affects the friction developed at the sleeper's side-ballast interface. End restraint is primarily dependent upon the ballast shoulder geometry and its ability to resist sleeper movement through ballast shearing resistance (i.e. an increase in shoulder width will generally increase sleeper end restraint).

If ballast is missing from the shoulders or cribs, the ability for track to resist lateral movement will be reduced. Reducing the friction bond between the ballast and sleeper through track maintenance can reduce the track's ability to resist lateral movement by more than 50 per cent.

Following track maintenance such as ballast cleaning or tamping for surface and alignment, there will be a period of time over which the friction bond will improve as the ballast consolidates until maximum resistance is obtained. Compaction of the ballast layer under traffic or using mechanical stabilisation will reduce the time to achieve maximum resistance to lateral movement.

It should also be recognised that timber sleepers gain much of their friction properties when the sharp angular edges of ballast embed into the timber. However, this process takes time and repeated loading to achieve maximum ballast penetration. New timber sleepers with a low degree of penetration may exhibit 20 per cent to 30 per cent less lateral resistance than old timber sleepers which have a high degree of particle penetration¹¹.

While time and repeated loading may assist timber sleepers to gain maximum particle penetration, it can also cause ballast to break down into smaller pieces and eventually fine particles of silt. Ballast that has broken down in this manner is sometimes referred to as a glazed ballast bed. If the sharp angular edges also break down and the ability of the ballast to penetrate timber is reduced, the friction bond between the timber sleeper and the ballast is also reduced.

A lateral misalignment is likely to develop when lateral forces exerted on the track structure exceed the track structure's ability to resist lateral movement. Given sufficient lateral force, even undisturbed track may move. However, if the friction

11 ROA "A Review of Track Design Procedures", Volume 1 "Rails"

bond between sleeper and ballast is reduced, the magnitude of lateral force required to overcome lateral resistance is significantly less.

It is also important to note that if a misalignment is to occur, it will likely occur at the weakest point in the track structure. This may only be a short isolated piece of track in an otherwise very stable section.

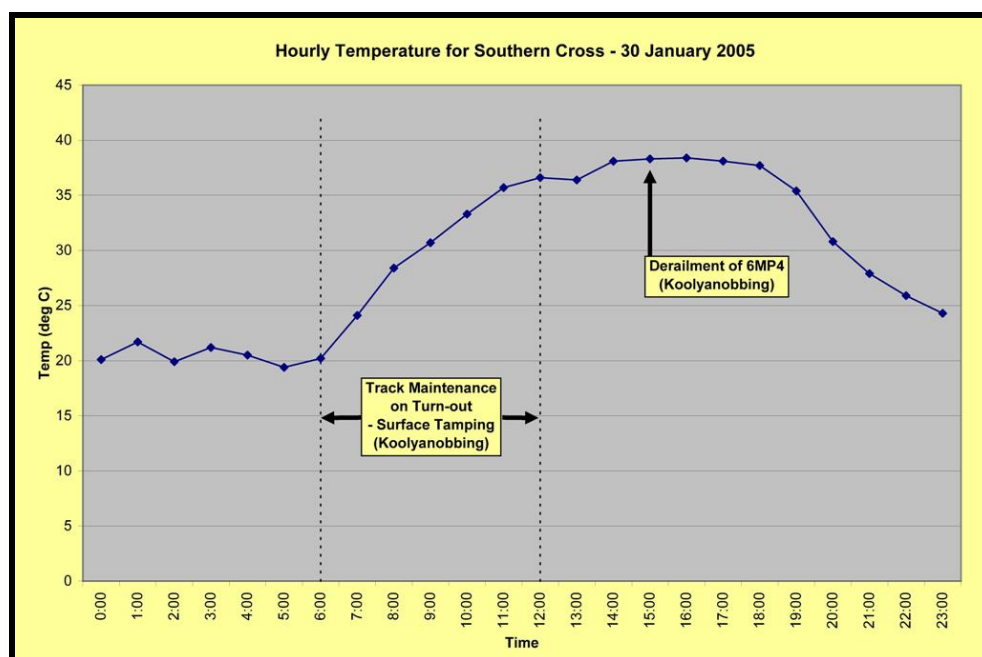
Koolyanobbing

When considering the track structure through the turn-out at Koolyanobbing, the rail was supported on timber sleepers, and was in good condition with a full ballast profile for both shoulder and crib. This configuration would normally provide appropriate resistance against lateral track instability.

However, the turn-out at Koolyanobbing had been subjected to recent track maintenance which would have reduced consolidation of the ballast and the friction bond between the sleepers and the ballast. Ten days earlier, on 20 January 2005, nine sleepers were replaced between the turn-out's heel block and vee crossing. Post accident observation showed displaced ballast indicating misalignment of sleepers in this area. It is likely that the replacement timber sleepers exhibited a reduced friction bond with the ballast due to a lower degree of particle penetration. While rail traffic over the following ten days would serve to increase ballast consolidation it is unlikely that maximum lateral resistance would have been achieved.

On the morning that the derailment occurred, track tamping was conducted over the turn-out as part of an ongoing turn-out maintenance programme. It is likely that a reduced friction bond due to replaced sleepers, compounded by track tamping loosening the ballast and further reducing the friction bond between sleeper and ballast, contributed to a reduced resistance against lateral movement.

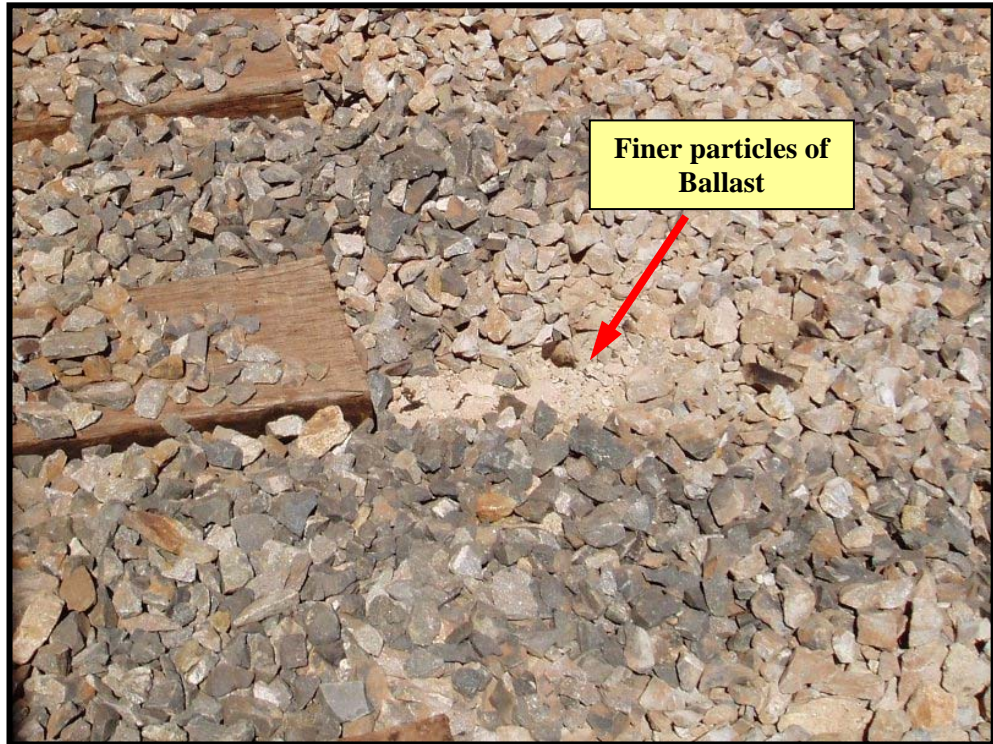
Figure 11: Hourly temperatures in the vicinity of Koolyanobbing showing the time during which track tamping was conducted and the time of derailment



Data sourced from Bureau of Meteorology

While a reduced resistance against lateral movement was likely and longitudinal forces within the rail were in compression and likely to increase the risk of track misalignment, in this case these alone were not sufficient to cause a misalignment in the form of a track buckle in well constructed and maintained track. However, three hours after completion of track tamping, 6MP4 encountered a track misalignment and derailed.

Figure 12: Broken down ballast



Another factor that may have contributed to a reduction in lateral stability is the possible break down of ballast. Figure 12 illustrates a sleeper that may be supported, at least partially, on finer particles of ballast. However, the investigation concluded that the contribution to reduced lateral stability that ballast breakdown provided was likely to be minor when compared to the effect of track maintenance.

Again, reduced resistance against lateral movement due to sleepers supported on degraded ballast alone is not sufficient in this case to cause a misalignment in the form of a track buckle. A lateral force must be applied to the rail and sleepers such that their resistance is exceeded and the track structure is permitted to move laterally.

Booraan

The track at the Booraan derailment site had been subjected to recent track maintenance. Eight days earlier, on 22 January 2005, five sleepers either side of the level crossing were lifted and packed, and a slight adjustment to alignment was conducted approximately 20 metres east of the level crossing. The work was conducted using manual tools and procedures which are unlikely to disturb the track as much as tamping using track machines.

It is unlikely that this work directly contributed to the derailment of 6SP5, as it was approximately 80-100 metres beyond the probable location of the misalignment. However the fact that minor adjustment to alignment was required east of the level crossing is of some significance. Small alignment defects are a potential warning sign that undetected track stability problems may be present in the immediate area.

Track maintenance using track machines had been conducted in the Booraan area almost two months earlier, on 3 December 2004. The recorded maximum temperature on this day was 29.8°C. While track maintenance may contribute to a reduction in lateral track stability, subsequent rail traffic operating over the site would have assisted in restoring the lateral stability of the track. As such, it is unlikely that this work itself would have directly contributed to the derailment of 6SP5. It is possible that the rail could have experienced longitudinal movement in the period when the ballast bed was unconsolidated during and immediately following this work. The lack of monitoring points for rail creep at this location made it impossible to confirm or deny such movement.

When considering the track structure at Booraan, the rail was supported on concrete sleepers, was in good condition, and had a full ballast profile for the crib. However, the ballast profile did not demonstrate a full shoulder width in all areas. Figure 13 shows the rear half of freight wagon CQGY0508 which was coupled behind the last derailed wagon of 6SP5. Survey measurements¹² indicate no lateral track deflection in this area, implying minimal or no track disturbance. The inset diagram illustrates the estimated actual ballast profile for sections of track structure immediately before the derailment site and what would be considered a full ballast profile.

Figure 13: Ballast Shoulder

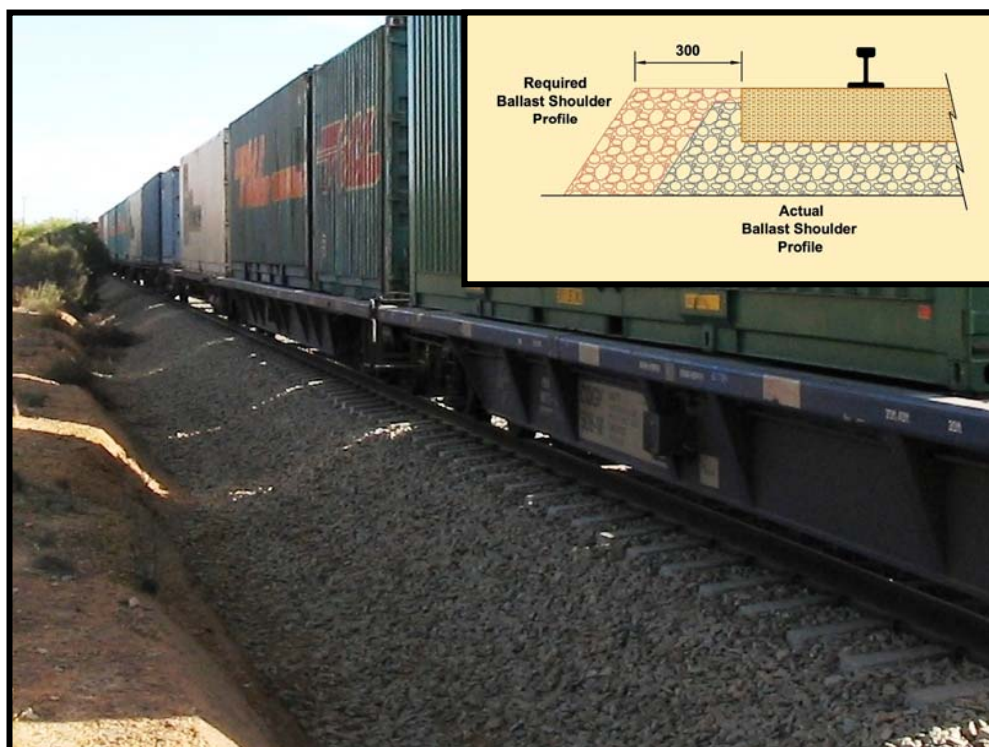


Photo by WestNet Rail

12 Survey conducted by Licensed Surveyors on 3 February 2005

While ballast may provide approximately 60 per cent of a track structure's lateral resistance, this generally comprises of 20 per cent bottom, 30 per cent side, and 10 per cent shoulder components¹³. Even though the shoulder component may provide the least effect, a track section where the shoulder profile is reduced is still likely to exhibit a lower resistance to lateral movement when compared to a track section with a full shoulder.

Indicators in the Booraan area point to factors that could have contributed to reduced levels of resistance against lateral movement. However, these factors alone are not sufficient in this case to cause a misalignment in the form of a track buckle. A lateral force must be applied to the rail and sleepers such that their resistance is exceeded and the track structure is permitted to move laterally.

3.2.3 Dynamic Rail Forces

When considering lateral stability, dynamic forces result in three primary consequences:

- direct application of lateral force to the rail and sleepers
- dynamic rail uplift between rollingstock bogies
- a change in the rail neutral temperature.

As a rail vehicle traverses a track, it is common for vehicle movement to apply lateral forces to the track structure via wheel flange contact on the rail; however, normally these forces will not be significant. Track alignment or surface deviations can influence the lateral movement of a vehicle, as can the train handling techniques adopted by the locomotive driver. As the lateral movement of a rail vehicle increases, so will the lateral forces applied to the track structure. Similarly, inappropriate rollingstock design, loading or faulty rollingstock suspension can encourage bogie hunting¹⁴ and increase the lateral forces applied to the track structure.

If the lateral forces applied through vehicle movement exceed the ability of the track structure to resist lateral movement, a track misalignment will develop. A misalignment in the form of a buckle will usually begin as a small deviation or kink. Each passing of a rail vehicle can increase the misalignment until the track shifts more rapidly and a buckle occurs.

Dynamic rail uplift is a phenomenon that occurs with heavy axle loads on moving vehicles. As a vehicle moves, the track structure under each bogie compresses with a corresponding uplift between the bogies. In extreme cases, the sleeper bottom can lose contact with the ballast, reducing or eliminating that component of lateral resistance. The applied vehicle loading, vehicle dimensions, track weight, and track vertical modulus (stiffness of track support) define the magnitude and extent of dynamic uplift.

Dynamic uplift and rollingstock induced lateral forces can usually be detected visually; however, changes in the rail neutral temperature are much more difficult to detect. Track with no apparent visual indicators of track misalignment or

¹³ ROA "A Review of Track Design Procedures", Volume 1 "Rails"

¹⁴ Bogie hunting refers to the severe side to side movement of a bogie as it travels along the track.

buckling has been known to buckle ahead of, or beneath, a passing train. In severe cases, the track may buckle without any trains being present.

The action of a train moving along track can initiate rail creep¹⁵. Rail will usually creep in the direction of travel. On level track with traffic in both directions, creep in one direction will counter the creep in the other, resulting in minimal total creep. However, on a gradient rail will usually creep downwards regardless of the direction of travel. Rail creep causes a redistribution of longitudinal forces within the rail, usually resulting in a bunching effect at the bottom of gradients or at fixed points such as level crossings. The resultant increase in longitudinal compressive force within the rail can also be expressed as a reduction in the effective rail neutral temperature.

Koolyanobbing

Following the track maintenance work conducted over the turn-out at Koolyanobbing, only one train movement occurred before the arrival of train 6MP4. Perth bound train 6SP5 traversed the turn-out at Koolyanobbing approximately 75 minutes before the derailment of 6MP4 and did not report any track misalignment. However, 6SP5 would have exerted a lateral force on the weakened track structure.

There was no evidence to suggest any inappropriate train handling by either the driver of train 6MP4 or 6SP5. Only the act of braking train 6MP4 following the observation of the misalignment may have resulted in an increase in the lateral forces exerted by the rail vehicles as they traversed the misalignment.

The Koolyanobbing derailment site was located within a turn-out immediately before a level crossing at the bottom of a slight descending gradient. In the event of any rail creep in this area, the turn-out and the level crossing would present fixed points that could encourage a bunching effect in the rail, effectively lowering the rail neutral temperature at this location.

Booraan

A Sydney bound train (1PS6) traversed the Booraan derailment site almost two hours before the derailment of the Perth bound 6SP5 and did not report any track misalignment. However, 1PS6 would have exerted a lateral force on a potentially weakened track structure.

As for Koolyanobbing, there was no evidence to suggest any inappropriate train handling by either the driver of train 6SP5 or 1PS6. The braking technique implemented by the driver of 6SP5 aimed to keep the train 'stretched' while gradually slowing the train in a controlled manner. This technique transfers the minimum level of lateral force to the track and is consistent with an attempt to ride a train through a minor track misalignment. However, it is likely that the act of braking increased the lateral forces exerted by the rail vehicles as they traversed the misalignment.

¹⁵ Rail creep is the movement of rail in the longitudinal direction

The track structure at Booraan was in good condition and incorporated 60kg/m CWR on concrete sleepers. This produces a very heavy and stable track such that dynamic rail uplift would be unlikely.

The slight descending gradient at the Booraan derailment site is located immediately before a level crossing. In the event of any rail creep in this area, the level crossing would present a fixed point that would encourage a bunching effect, effectively lowering the rail neutral temperature at this location.

Track maintenance using track machines had been conducted in the Booraan area almost two months earlier, on 3 December 2004. The recorded maximum temperature on this day was 29.8°C. Based on the maintenance records, it is evident that the track machine was working in the direction of the descending gradient and towards the level crossing (fixed point).

A minor misalignment, located immediately before the level crossing, was repaired eight days before the derailment of 6SP5. It is possible that this could be interpreted as a warning sign of an undetected track stability problem such as a lowering of neutral temperature.

3.2.4 Summary of Track Misalignment and Stability

Koolyanobbing

Further analysis identified the following factors that may have contributed to a misalignment developing within the turn-out at Koolyanobbing:

- It is likely that, at the time of the derailment, compressive longitudinal forces existed within the rail due to a recorded rail temperature 18°C higher than the design neutral temperature of 40°C.
- Ten days before the derailment of 6MP4, on 20 January 2005, a number of sleepers were replaced within the turn-out at Koolyanobbing. It is likely that the replacement timber sleepers resulted in a reduced friction bond with the ballast due to a lower degree of particle penetration. While rail traffic over the following ten days may have increased ballast consolidation it is unlikely that maximum lateral resistance would have been achieved.
- On the morning that the derailment occurred, track tamping was conducted over the turn-out as part of an ongoing turn-out maintenance programme. It is likely that a reduced friction bond due to replacement sleepers, compounded by track tamping further reducing the friction bond between sleeper and ballast, contributed to a reduced resistance against lateral movement.
- It is likely that the passage of 6SP5, approximately 75 minutes before the derailment of 6MP4, exerted lateral force onto the weakened track structure, and caused some lateral track movement. It is possible that the bond between the sleeper and the ballast may have broken, substantially reducing the track structure's resistance against lateral movement. If the resistance against movement reduced sufficiently to allow the track to move laterally, it is likely that a misalignment would have developed under train 6SP5. However, the misalignment would not have been of sufficient magnitude as to derail train 6SP5, nor likely to have been detected by the driver of 6SP5.

- It is likely that the misalignment was not of sufficient magnitude to immediately derail 6MP4, allowing approximately 200 metres of train to traverse the misalignment. However, the misalignment caused severe lateral movement of the rail vehicles which further increased the misalignment until wagons ultimately derailed.
- It is possible that longitudinal rail movement may have occurred over time, even though the track structure design at Koolyanobbing was resistant to longitudinal rail movement. Consequently, the turnout and adjacent level crossing accompanied by a slight descending gradient would encourage compressive forces within the rail, effectively lowering the rail neutral temperature at this location. An effective neutral temperature lower than the design neutral temperature would increase the influence of thermal expansion on a developing track misalignment.

Booraan

Further analysis identified the following factors that may have contributed to a misalignment developing at Booraan:

- It is likely that, at the time of the derailment, compressive longitudinal forces existed within the rail due to a recorded rail temperature 21°C higher than the design neutral temperature of 40°C.
- It is likely that the track structure demonstrated a reduced resistance to lateral movement due to a deficient ballast shoulder profile in some areas.
- It is likely that a minor alignment defect repaired eight days before the derailment of 6SP5 may have indicated a potential track stability problem at the Booraan derailment site. This possibility becomes more likely when considering that the adjacent level crossing presents a fixed point in the track structure where any rail creep would result in a lowering of the effective rail neutral temperature.
- It is likely that the passage of 1PS6, approximately two hours before the derailment of 6SP5, exerted lateral force onto a potentially weakened track structure, and caused some lateral track movement. It is possible that the bond between the sleeper and the ballast may have broken, substantially reducing the track structure's resistance against lateral movement. If the resistance against movement reduced sufficiently to allow the track to move laterally, it is likely that a misalignment would have developed under train 1PS6. However, the misalignment would not have been of sufficient magnitude as to derail train 1PS6, nor likely to have been detected by the driver of 1PS6.
- It is likely that the misalignment was not of sufficient magnitude as to immediately derail 6SP5 allowing approximately 600 metres of train to traverse the misalignment. However, the misalignment progressively increased lateral movement of rail vehicles, further increasing the misalignment until wagons ultimately derailed.
- It is possible that longitudinal rail movement may have occurred over time, even though the track structure design at Booraan was resistant to longitudinal rail movement. Consequently, the slight descending gradient and the adjacent level crossing would encourage compressive forces within the rail, effectively lowering the rail neutral temperature at this location. An effective neutral temperature lower than the design neutral temperature would increase the influence of thermal expansion on a developing track misalignment.

- It is possible that track maintenance work may have encouraged a redistribution of longitudinal rail forces. The track at the Booraan derailment site had been subjected to track tamping approximately two months before the derailment of 6SP5. Since the tamping work was conducted while travelling on the down gradient towards the level crossing, the most likely redistribution would be slight creep in the direction of travel. Similarly, a period of reduced track stability would follow the tamping work, during which time the dynamic forces applied by train operations may also result in slight creep towards the level crossing. While not considered a direct contributor to the derailment of 6SP5, any incremental rail creep over time would have a cumulative effect. However, the lack of monitoring points for rail creep at this location made it impossible to confirm or deny such movement.

3.3 Rollingstock

The analysis presented so far suggests that the most probable cause for both derailments was a track misalignment in the form of a buckle. However, the possibility remained that a rollingstock factor may have contributed to one or both derailments.

To assist the ATSB, a technical specialist with expertise in rollingstock design and maintenance was engaged to examine and provide analysis of the derailed wagons to determine if any elemental or systemic characteristic of the rollingstock could have contributed to the derailments. The derailed wagons were verified for compliance against the Code of Practice (COP) for the Defined Interstate Rail Network, Volume 5, Rollingstock.

3.3.1 Pacific National train 6MP4 - Koolyanobbing

Pacific National train 6MP4 consisted of two NR class diesel electric locomotives, followed by 48 freight wagons (nine of which were 5-unit wagons). The train length was 1685 metres for a total train weight of 4108 tonnes. A total of 23 wagons were derailed (four of which were 5-unit wagons).

Damage to civil infrastructure and the post derailment location of wagon components suggested that the most likely wagon to have derailed first would be one of the three derailed wagons positioned closest to the locomotives. The three wagons quarantined for further examination are detailed in Table 3.

Most of the bogies appeared to have been overhauled recently as the side bearers were in excellent working condition. Pieces of the manufacturer's sticker were still visible on the contact pads on the side bearers. The flange height, thickness and rim thickness for all wheel-sets were within the limits specified in the rollingstock code of practice. Some tread hollowing was observed; however, these too were within the limits specified in the rollingstock code of practice.

Table 3: Documented details for Pacific National wagons

Element	Wagon Number		
	RQJW22060	RQFY00031	NQSY34992
Wagon Type:	Container Flat Wagon	Container Flat Wagon	Container Flat Wagon
Unit length:	25.6 m	20.1 m	20.1 m
Tare mass:	27 tonnes	22 tonnes	22 tonne
Gross mass:	80 tonnes	80 tonnes	78 tonne
Payload capacity:	55 tonnes	58 tonnes	56 tonne
Maximum speed:	115 km/h @ 78 tonne	115 km/h @ 78 tonne	115 km/h
	110 km/h @ 80 tonne	80 km/h @ 80 tonne	
Number in Class:	125	111	23
Date first built:	1975	1978	1974

Many of the secondary suspension springs were dislodged during the derailment and were missing from the bogies, but an examination of the snubbing devices showed that the devices were working at the time of the derailment. All wear plates in the bearing pedestals appeared to be relatively new and showed minimal wear.

An examination of the draft gear and couplers showed that they were in good working condition.

3.3.2 Pacific National train 6SP5 - Booraan

Pacific National train 6SP5 consisted of two NR class diesel electric locomotives, followed by 46 freight wagons (13 of which were 5-unit wagons). The train length was 1740 metres for a total train weight of 3739 tonnes. A total of 19 wagons were derailed (four of which were 5-unit wagons).

Damage to civil infrastructure and the post derailment location of wagon components suggested that the most likely wagon to have derailed first would be one of the three derailed wagons positioned closest to the locomotives. The three wagons quarantined for further examination are detailed in Table 4

Table 4: Documented details for Pacific National wagons

Element	Wagon Number		
	RQSY34494	RRAY7175	RQNW60034
Wagon Type:	Container Flat Wagon	Container Flat Wagon (5-unit Articulated)	Container Flat Wagon
Unit length:	20.1 m	73.1 m	25.7 m
Tare mass:	22 tonnes	53 tonnes	23 tonnes
Gross mass:	80 tonnes	276 tonnes	80 tonnes
Payload capacity:	58 tonnes	223 tonnes	57 tonnes
Maximum speed:	115 km/h @ 76 tonne	115 km/h @ 228 tonne	115 km/h @ 76 tonne
	110 km/h @ 84 tonne	110 km/h @ 252 tonne	110 km/h @ 80 tonne
	80 km/h @ 92 tonne	80 km/h @ 276 tonne	
Number in Class:	206	98	23
Date first built:	1974	1996/97	1973

The three piece bogies situated at the articulated joints on the 5-unit wagon (RRAY7175) showed the greatest wear in the centre plates and in the friction pockets. It is possible that the friction shoe pocket wear may have reduced the bogies' ability to square up and may have allowed the wheel-sets to lozenge¹⁶. This is reflected in the wheel wear on these bogies which, while greater than other wheel-sets, is still within the limits specified in the rollingstock code of practice.

It is also possible that the heavy wear in the centre plate may have increased the bogies' rotational stiffness. The wear pattern was such that it may have allowed the centre plate to be keyed into the top centre plate of the wagon. While increased wear may have resulted in increased rotational stiffness on tighter curves, it was unlikely to have contributed to the derailment of 6SP5 for two reasons. Firstly, the curves leading into both derailment sites were large radius curves rated at 110 km/h which would only require minimal bogie rotation. Secondly, as discussed in section 3.6, these bogies were unlikely to have been the first to derail and more likely to have derailed as a consequence of the derailment of the three wagons detailed in Table 4.

The rigid bogies on wagons RQSY34494 and RQNW60034 showed lower levels of wear when compared to the three piece bogies. Similarly, the wheel-sets on the rigid bogies showed lower levels of wear, with the flange height, thickness and rim thickness all within the limits specified in the rollingstock code of practice.

The centre plate on the rear bogie of wagon RQSY34494 showed bruising and wear from travelling while dislodged from the wagon body. The same bogie exhibited flattening of the left side wheel flanges (in direction of travel). The centre plate of the dislodged body of wagon RQSY34494 was found to be resting on the left edge of the bogie centre plate. With the five following RRAY wagon bodies dragging (without the rear five bogies) for some distance along the left hand ballast shoulder, the forces acting on the body of wagon RQSY34494 would have created a tendency for it to rock and tilt to the left. Examination of the wheel flanges, centre plate and wagon body found that the wear was consistent with rubbing on the wagon body. The magnitude of wear also appeared consistent, considering the likely dynamics exerted by the dragging RRAY wagon following behind. This type of wear has been observed in other freight train derailments where a dislodged bogie has caused the wheel flanges to rub on the wagon body.

Of the three wagons from 6SP5 which were quarantined for further examination, two wheels on two separate wheel-sets had moved off their normal axle seating position. The relevant wheel-sets were located on the third and fourth bogies positioned under wagon RRAY7175. On one wheel-set, the wheel had moved fully off the wheel seat while on the other wheel-set the wheel had only moved to the edge of the wheel seat.

The records available indicated that wheels had not been replaced on either wheel-set since the wheel-sets were originally constructed. Both wheel-sets were installed new under a RRZY class wagon, originally built in 1995. In January 2002, the wheel-sets were removed from the RRZY wagon, the wheels were re-profiled and

¹⁶ For a three-piece bogie the tendency for relative longitudinal displacement between the side frames, resulting in misalignment (out-of-square) of the wheelsets and bolster (Draft ARA Code of Practice - Volume 5 Rollingstock).

the bearings reconditioned. In September 2002, the wheel-sets were placed under wagon RRAY7175 where they remained until the derailment of 6SP5.

Figure 14: Wheel moved fully off the wheel seat



Photo by WestNet Rail

An examination of the wheel-sets showed no evidence to suggest that the wheels had moved before the derailment of 6SP5. Considering the history of the wheel-sets, it is unlikely that the wheels moved off their respective wheel seats under normal running conditions. The most likely cause for the movement of the wheels was an impact during the derailment of 6SP5. This is not uncommon during heavy freight wagon derailments of this magnitude.

3.3.3 Summary of Rollingstock

There was considerable damage to wagon structures and bogies due to the derailments at Koolyanobbing and Booraan. The rollingstock was examined and verified as complying with the minimum requirements documented in the rollingstock code of practice. There was no rollingstock defect identified that could be considered as causing or contributing to either derailment. Similarly, there was no deficiency in rollingstock maintenance practices or procedures that could be considered as contributing to either derailment.

Section 3.6 provides further discussion regarding analysis of specific rollingstock observations and possible alternative derailment mechanisms.

3.4 Standards and Procedures

Standards and procedures are developed over time not only to encourage consistent outcomes of a specific task, but to manage an organisation's exposure to safety related risks. It is the role of standards and procedures to assist in preventing an environment developing whereby this form of misalignment is permitted to develop.

In general, the track structures at both Koolyanobbing and Booraan were considered to provide good resistance to lateral and longitudinal rail movement. However, while the risk of a track buckle may be greater on poor condition track, a buckle can occur on track maintained to a good condition.

There are many factors that may contribute to a track buckle; however, for this investigation, analysis of standards and procedures focused primarily on the following issues related to identified contributing factors (refer to Section 3.2.4 'Summary of Track Misalignment and Stability').

- High ambient temperature resulting in a rail temperature significantly higher than the design neutral temperature.
- Longitudinal rail movement and/or track maintenance causing a redistribution of longitudinal rail forces, thereby modifying the effective rail neutral temperature.
- Reduced resistance against lateral track movement due to track maintenance works.
- Deficient ballast shoulder profile exposing the track structure to reduced resistance against lateral track movement.
- Recognition of a minor alignment defect as a warning sign of a potential track stability problem.

The relevant standards and procedures were analysed, not only to determine if actions conformed, but to identify their suitability to manage the risk of derailment due to a track misalignment in the form of a buckle. WestNet Rail has developed and published a *Standard Gauge Mainline Code of Practice, Track & Civil Infrastructure*. This Code of Practice (COP) documents the minimum standards and practices which if adopted are deemed to comply with WestNet Rail's obligations under their rail safety accreditation.

3.4.1 General

The WestNet Rail COP documents two methods of infrastructure management relevant to the standard gauge main line:

- management of general infrastructure
- management of infrastructure at hazard locations.

In general, a regime of inspection, assessment and maintenance is adopted to ensure that the infrastructure is maintained to a standard consistent with its function. However, some locations may exhibit a history where a specific event may reduce the infrastructure's ability to maintain the required standard.

For example, a location may be susceptible to occasional flooding which may reduce the track stability in that area. For this example, the location would be defined as a 'hazard location' and flooding as a 'defined event'. Similarly, a

location may be susceptible to lateral instability such that hot weather may induce buckling. Again, the location would be defined as a ‘hazard location’ while hot weather as the ‘defined event’.

Locations defined as ‘hazard locations’ require additional assessment to determine the maintenance regime appropriate to manage the infrastructure’s ability to accommodate the defined event. WestNet Rail did not consider the Koolyanobbing or Booraan areas as hazard locations susceptible to lateral instability. Therefore occurrences of high ambient temperature were not trigger events for unscheduled inspections.

3.4.2 Track Design

Track design, construction and commissioning aims to create an infrastructure system that conforms to the appropriate standards and is compatible with functional and operational parameters. Analysis of the track design parameters, in relation to track lateral stability, determined that the track structure at both Koolyanobbing and Booraan was consistent with the designed parameters documented in WestNet Rail’s COP. However, track and civil infrastructure is a system of components which deteriorate in condition through a number of factors including usage and aging. It is the role of the monitoring, assessment and maintenance process to ensure that the infrastructure condition stays within the designed maintenance limits.

3.4.3 Track Condition Monitoring

Track condition monitoring is primarily achieved through track inspection. Inspections may be either scheduled or unscheduled and take the form of patrol inspections, general inspections or detailed inspections.

Scheduled inspections provide the basis for a preventative maintenance regime. Inspections start when the infrastructure is new and continue throughout its operational life. They generally involve a documented schedule of regular (eg. weekly) patrols conducting visual inspection of track condition. The regular patrols are supplemented by scheduled (eg. bi-annually) general and detailed inspections where visual observation and measurement may look at specific aspects of the infrastructure condition or behaviour.

Unscheduled inspections are usually event initiated. Depending on the initiator, the inspection may be a visual patrol or a more detailed assessment of the infrastructure condition or behaviour. For example, a day of extreme temperature may prompt a visual patrol, whereas a reported track defect may prompt a more detailed inspection.

Hazard locations are treated the same as other infrastructure locations except that for scheduled inspections consideration must be given to conditions that may compromise the infrastructure’s integrity during a defined event. Alternatively, the occurrence of a defined event is likely to initiate an unscheduled inspection.

Koolyanobbing

A number of factors were identified that may have contributed to a misalignment developing within the turn-out at Koolyanobbing. However, these factors were

primarily related to the weakening of the track structure's resistance to lateral movement, due to maintenance work carried out earlier on the day of derailment. Track condition monitoring through scheduled track inspections is not relevant in this case since this is not a defect caused through infrastructure deterioration.

The track defect related factor identified that may have contributed to the derailment of 6MP4 at Koolyanobbing was the possibility that the effective rail neutral temperature was lower than designed due to a redistribution of longitudinal rail forces. Changes in rail neutral temperature are very difficult to detect visually unless longitudinal forces within the rail cause further track defects.

There was no suggestion that scheduled track patrols were deficient in their task of monitoring the track as required by WestNet Rail's COP. WestNet Rail did not consider the Koolyanobbing area a hazard location susceptible to lateral instability. Therefore occurrences of high ambient temperature were not trigger events for unscheduled inspections.

Booraan

A number of factors were identified that may have contributed to a misalignment developing at Booraan. As previously mentioned, only defect related factors are likely to be detected through scheduled track inspections.

The track structure at Booraan was generally in good condition with the exception that some areas exhibited a reduced ballast profile. For example, in Figure 13 the ballast profile was estimated as $\frac{1}{4}$ shoulder width with $\frac{3}{4}$ shoulder height. For this level of defect during the buckle prone season, WestNet Rail's COP states that follow-up action is required to restore the track with an appropriate increase in monitoring. However, the COP also allows for a level of interpolation when reduced ballast profile is observed. The response criteria are relevant to ballast profile deficiencies occurring over lengths of 10 metres or greater. A possible track defect related factor that may have contributed to the derailment of 6SP5 at Booraan was a lower effective rail neutral temperature than the design parameter, due to a redistribution of longitudinal rail forces. It is significant that a minor alignment defect was detected approximately 20 metres before the level crossing at Booraan. This defect was repaired eight days before the derailment of 6SP5; however, it was not identified as being a potential warning sign that track stability may be a problem in the area.

While there was no suggestion that scheduled track patrols were deficient in their task of monitoring the track as required by WestNet Rail's COP, there remains the opportunity to improve the assessment of patrol observations. WestNet Rail did not define the Booraan area as a hazard location susceptible to lateral instability. However, it should be recognised that track instability problems are not confined entirely to hazard locations. Irrespective of an area being considered as resistant to lateral and longitudinal rail movement, assessment should consider that a minor track defect may be a warning sign of undetected track instability problems.

3.4.4 Track Maintenance

WestNet Rail's COP documents the actions required as track inspections identify deterioration over time and usage. The appropriate action is dependent on the level of deterioration and may vary from increased monitoring to repair and removal of

the defective condition. If immediate repair is not possible, restrictions may be applied to rail operations.

Koolyanobbing

The investigation determined that the track structure at Koolyanobbing had, most likely, been exposed to a significant reduction in resistance against lateral track movement due to the replacement of sleepers ten days before, and track tamping over the turn-out three hours before the derailment of 6MP4. This would imply that a contributing factor to the derailment was the maintenance function itself, and not a lack of maintenance. WestNet Rail's COP does not specifically document requirements for track maintenance which consider the affect the maintenance may have on track stability, especially when this maintenance function is conducted in high ambient temperatures.

Replacement of sleepers and tamping is included in the design and construction part of the COP so such work could be interpreted as more than general maintenance.

The design section of WestNet Rail's COP states:

When performing track infrastructure works including resleeping, reballasting, resurfacing, rerailing and distressing that would cause track instability, the safe operating temperature, should be:

- *Concrete Sleepered Track* $\leq 60^{\circ}\text{C}$ rail temperature
- *Steel / Timber Sleepered Track* $\leq 58^{\circ}\text{C}$ rail temperature

However, WestNet Rail's COP does not specifically define 'Safe Operating Temperature', instead making reference to a 'Railways of Australia' (ROA) document¹⁷. It should be noted that the ROA document discusses lateral track stability in terms of 'explosive' and 'progressive' track buckling "... *provided that there are no external vehicle induced loads applied to the track*". Or in other words, track buckling due to temperature induced forces only.

The maintenance work at Koolyanobbing was conducted between approximately 0600 and 1200. During this time, the recorded rail temperature at the level crossing did not exceed 56.5°C. Based on this information, the work was conducted in accordance with the limits defined in the COP. However, less than two hours after completion of track maintenance, 6SP5 travelled through Koolyanobbing at 100 - 110 km/h. By this time, the recorded rail temperature had exceeded 58°C.

The construction section of WestNet Rail's COP states:

The effect of tamping the track reduces the track resistance to buckling by as much as 50%. In order to ensure track safety in high temperatures, precautions such as speed restrictions must be instituted, if deemed to be appropriate.

However, the track work conducted at Koolyanobbing was a little more than just track tamping. The replacement of timber sleepers ten days before the derailment of 6MP4 may have reduced the lateral resistance, initially at least, by 20 per cent to 30 per cent, while track tamping may reduce track resistance by as much as 50 per

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cent¹⁸. As it can take some time for the track structure to regain its lateral resistance and stability, it is not uncommon for a speed restriction to apply until a defined traffic load has traversed the location. This effectively reduces train induced lateral force while allowing vertical force to restabilise the track structure.

Considering the type of track work conducted, and the likely reduction in track lateral resistance and stability, the application of a speed limit may have been the appropriate action.

Booraan

Unlike the Koolyanobbing location, no track maintenance work had recently been conducted that may have reduced the track lateral stability. The most recent work consisted of track tamping approximately two months before the derailment of 6SP5, and a minor alignment defect repaired eight days before the derailment of 6SP5. Neither is likely to have reduced the track lateral stability on the day of derailment; however, the minor track defect may have indicated a potential track stability problem at the Booraan derailment site.

3.4.5 Maintenance Model

As previously described, infrastructure maintenance as documented in WestNet Rail's COP is based on a regime of monitoring to detect defects, assessment to determine the required response and corrective action to repair the defect. The primary tool adopted for the monitoring function is visual inspection through scheduled patrols. This approach is suitable where an infrastructure defect is easily detected visually; however, becomes inappropriate if the defect is hidden.

For example, the investigation identified that longitudinal rail movement may have occurred over time causing a redistribution of longitudinal rail forces thereby modifying the effective rail neutral temperature. However, longitudinal rail forces are invisible, allowing only defects caused by the forces to be observed visually unless a task specific rail creep detection system is in place.

WestNet Rail advised that the Koolyanobbing and Booraan derailment sites had no recorded evidence of lateral track instability defects, and were considered to provide good resistance against longitudinal rail movement. Consequently, neither the Koolyanobbing nor the Booraan derailment locations were identified by WestNet Rail as hazard locations and management of longitudinal rail movement was not considered a requirement.

Change in effective rail neutral temperature away from the design rail neutral temperature is an inherent infrastructure defect. However, no processes were in place to detect, assess or correct a rail neutral temperature defect.

WestNet Rail's COP is a little ambiguous when addressing the management of longitudinal rail movement. The COP states:

Track construction types that are known to provide very good resistance to longitudinal rail movement (eg CWR, resilient fastenings) may not require rail creep monitoring and control measures.

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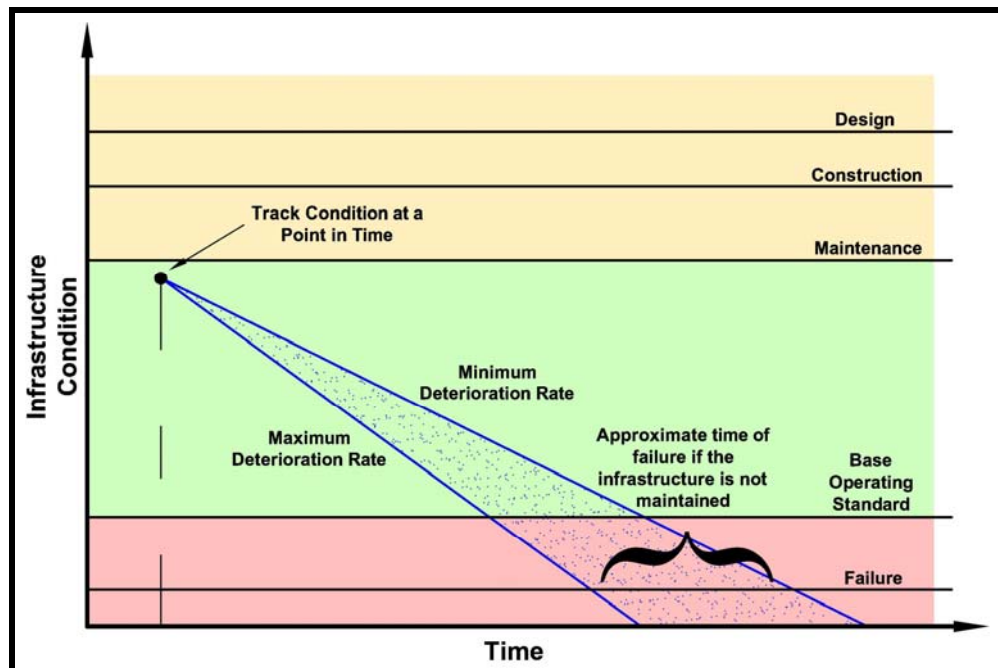
This would support WestNet Rail’s decision not to monitor and control longitudinal rail movement at Koolyanobbing and Booraan. However, the same paragraph also implies that methods for measuring longitudinal rail movement should be considered, when it states:

Practices for measurement of rail creep should be considered, and take into account the influence of fixed points in the track.

To resolve the ambiguity, the basis upon which the COP was developed was examined to determine the intent of the COP.

WestNet Rail’s maintenance model is based on a philosophy of ensuring a deteriorating infrastructure system is maintained to a condition above a defined minimum standard. A simple description of the model is a ‘Condition’ versus ‘Time’ graph that describes the life cycle phases of infrastructure condition. Figure 15 illustrates a simplified version of the maintenance model and does not illustrate inspection period or corrective action.

Figure 15: Infrastructure Maintenance Model



The model incorporates the following attributes:

- The ‘Design’ line represents the theoretical condition level to which the infrastructure has been designed.
- The ‘Construction’ line represents the actual condition level to which the infrastructure was originally built.
- The ‘Maintenance’ line represents the condition level that the infrastructure is returned to following maintenance to corrected defects.
- The ‘Base Operating Standard’ line represents the condition level below which the risk of failure is unacceptable.
- The ‘Failure’ line represents the condition level at which if operated on, will result in failure.

At any point in time, the infrastructure will exhibit a condition level after which progressive deterioration will occur over time. Operational experience and history will generally enable determination of maximum and minimum deterioration rates. It is the role of the infrastructure maintainer to implement a maintenance regime to ensure the condition level is periodically returned to that indicated by the 'Maintenance' line. However, if the infrastructure is not maintained effectively, it is inevitable that the condition will deteriorate until failure.

When considering infrastructure condition in terms of rail neutral temperature, a change in effective neutral temperature is a result of longitudinal rail movement. While track in good condition may provide good resistance against longitudinal rail movement, this does not mean that rail movement will not occur, only that movement will be less in comparison to locations with poor track structure. The fact that periodic track tamping is required demonstrates that the track does move and deteriorate over time.

As previously described, on a gradient longitudinal rail movement will usually occur downwards regardless of the direction of travel. The magnitude of movement is likely to be minor when track is in good condition. This may increase slightly during periods the track is temporarily weakened through track maintenance (ie tamping). Until the track returns to its maximum strength, in terms of resistance to movement, there is an increase in risk that the track may move longitudinally. Even the action of track tamping can cause longitudinal rail movement in the direction of tamper travel. While any rail movement may be minor, over time the resultant redistribution of longitudinal rail forces are likely to compound and concentrate at the bottom of gradients or at fixed points such as road level crossings.

This would indicate that irrespective of the track structure, infrastructure condition in terms of rail neutral temperature is likely to deteriorate over time. It would also indicate that the level of deterioration is likely to be greatest at the bottom of gradients or at fixed points such as level crossings. While the deterioration rate may be low for track providing good resistance against longitudinal rail movement, it will still deteriorate.

As longitudinal rail forces cannot be detected visually, the most common form of detection is to install and monitor creep markers. While creep markers are often placed on curves, especially those tighter than 800m radius, it is also common for fixed or bunching points to attract particular attention. Some track network managers annually monitor all CWR track for creep.

WestNet Rail advised that no processes were in place to monitor and control longitudinal rail movement at Koolyanobbing or Booraan. WestNet Rail considered the entire standard gauge main line to provide very good resistance against longitudinal rail movement. Consequently, methods for monitoring rail creep had not been implemented. While it may be correct that well restrained concrete sleepered track is not prone to longitudinal rail movement, this does not mean that movement will not occur.

The lack of rail creep monitoring also prevents verification that longitudinal rail movement contributed, or for that matter did not contribute, to the derailments at Koolyanobbing and Booraan.

Koolyanobbing and Booraan

Both Koolyanobbing and Booraan derailment sites were located on slight descending gradients, immediately before level crossings and a turnout at Koolyanobbing. In the event of any longitudinal rail movement, it is likely that this configuration would encourage compressive forces within the rail, effectively lowering the rail neutral temperature at these locations.

WestNet Rail advised that neither Koolyanobbing nor Booraan were considered hazard locations. Consequently there was no process in place to monitor or detect longitudinal rail movement. Similarly, defects in rail neutral temperature would remain undetected until increased forces within the rail resulted in further defects that could be detected visually.

The track structure at Booraan was subjected to track tamping on 3 December 2004, almost two months before the derailment of 6SP5. Based on maintenance records, it is evident that the track machines were working in the direction of the descending gradient and towards the level crossing (fixed point). It is likely that any rail movement during the track maintenance work, or during the period immediately following track maintenance, would have contributed to a bunching effect at the road level crossing.

The track maintenance regime creates repeated periods of weakened resistance against longitudinal rail movement. While any rail movement during these periods may be minor, over time the resultant redistribution of longitudinal rail forces are likely to compound and concentrate at the road level crossing.

As previously mentioned a minor misalignment at Booraan, located immediately before the level crossing, was repaired eight days before the derailment of 6SP5. This form of defect is a typical warning sign that undesirable rail neutral temperatures may be present. While the minor misalignment may have been promptly repaired, apparently there was no analysis conducted to determine the cause of the misalignment.

It is likely that the significance of the misalignment was missed due to WestNet Rail's belief that well restrained concrete sleepered track was not prone to lateral misalignment or longitudinal rail movement. Similarly, there is a belief that the 60 kg/m rail used to cater for heavier axle loads also provides a heavier more stable structure than lighter rail. In fact, the larger cross section increases the force generated by thermal expansion and reduces the track lateral stability¹⁹.

3.4.6 Other Procedures

WestNet Rail is accredited as an owner of rail infrastructure under Western Australia's Rail Safety Act 1998. Under this accreditation, West Net Rail is required to have a comprehensive safety management plan that "*identifies significant potential risks that may arise from the... construction or maintenance, of rail infrastructure...*", and has "*... appropriate safety standards... relevant to the safe... construction or maintenance, of rail infrastructure...*".

19 ROA "A Review of Track Design Procedures", Volume 1 "Rails"

As previously described, WestNet Rail's COP defines standards and procedures relevant to the safe construction and maintenance of rail infrastructure. WestNet Rail also recognises that the COP will not always cover all risks, therefore additional procedures are required to assist in preventing an environment developing whereby infrastructure failure is likely to occur and rail safety placed at risk. Similarly, the COP addresses the elements of design, construction and maintenance with consideration of normal operational limits. However, the risk remains that occasionally extreme conditions may result in these limits being exceeded.

To address these risks, a railway organisation will generally develop additional procedures, commonly focusing on specific tasks or functions conducted by the organisation.

Heat Speed Restrictions (HSR)

As discussed previously, longitudinal rail force due to thermal expansion is a primary factor contributing to track buckles. WestNet Rail's COP does not specifically address the actions required when temperatures exceed defined levels where the risk of track misalignment is increased. While procedures may not have been formally documented, an informal process has been implemented to manage the potential risk to safe rail operations due to high temperatures.

The process relies on maximum temperature forecasts obtained from the Bureau of Meteorology. Based on this forecast, a special train notice is published advising operators of the HSR that are to apply the following day. During the day, temperatures at specific locations are actively monitored via WestNet Rail's 'Remote Ambient Temperature System' (RATS). A designated person accesses RATS on an hourly basis and advises any modification to HSR in the event that site temperatures exceed defined limits. Train Controllers are responsible for communicating changes in HSR to train crews by the UHF radio network.

A slightly modified process applies over the weekend. On each Friday, the forecast is obtained for both Saturday and Sunday. Appropriate HSR are published and an 'On-Call Roster' issued to cover the active monitoring of temperature over the weekend. Again, the responsibility for communicating changes in HSR to train crews lies with train control.

While track supported on concrete sleepers has greater ability to resist lateral movement than track supported on timber, the risk of misalignment increases for both track structures as rail temperatures increase. WestNet Rail recognises this by reducing track speed based on ambient temperature and the type of track structure.

WestNet Rail's process specifies the required HSR over defined track sections. The track sections are determined based on their ability to resist lateral movement during periods of high ambient temperature. For the DIRN between Kalgoorlie and Merredin, the type of track structure (timber sleepers or concrete sleepers) is used to determine the defined track section for HSR purposes. Table 5 summarises the HSR in terms of track structure and ambient air temperature.

Table 5: HSR for defined track sections between Kalgoorlie and Merredin

Track Structure	Ambient Air Temperature			
	35°C	38°C	40°C	43°C
Timber Sleepers	70 km/h	60 km/h	50 km/h	40 km/h
Concrete Sleepers	-	-	80 km/h	70 km/h

Derived from WestNet Rail Table of Heat Speed Restrictions

WestNet Rail defined both the Koolyanobbing and Booraan locations as supported on concrete sleepers, even though approximately 200 metres of track at Koolyanobbing was supported on timber sleepers. HSR do not apply on the track section supported on concrete sleepers until the ambient air temperature exceeds 40°C. While the ambient air temperature came close to 40°C on the day of the two derailments, it did not actually exceed 40°C. Consequently, HSR were not applied.

As discussed previously, it is likely that the misalignment at Koolyanobbing existed before the arrival of train 6MP4. Consequently, the application or non-application of HSR for train 6MP4 cannot be considered a factor relating to its subsequent derailment. However, train 6SP5 traversed this location approximately 75 minutes earlier. Its speed would have had a direct influence on the lateral forces exerted onto the timber sleepered track structure.

The ambient air temperature at Koolyanobbing exceeded 35°C at approximately 1100 and had exceeded 38°C by 1400. If the track at Koolyanobbing had been defined as a timber sleepered section for the purpose of HSR, WestNet Rail's process would have required a 70 km/h HSR to be in place by the time train 6SP5 traversed this location at approximately 1345. However, WestNet Rail defined the track section containing Koolyanobbing as concrete sleepered track. Consequently, HSR were not applied and train 6SP5 traversed the timber sleepered track at approximately 105 km/h.

While the timber sleepered section of track at Koolyanobbing was relatively short (approximately 200 metres), it presented a section less able to resist temperature induced rail stresses than if it had been supported on concrete sleepers. Considering it is likely that the track had been disturbed by track tamping, the application of HSR over this section of track may have been appropriate.

Track Maintenance

John Holland Rail Pty Ltd is contracted to undertake the WestNet Rail's track maintenance function. However, it should be recognised that WestNet Rail is the accredited owner, and primarily responsible for the safe construction and maintenance of rail infrastructure. Even the contractual arrangement between WestNet Rail and John Holland Rail is, in effect, a 'labour hire' type contract. Under these arrangements, WestNet Rail inspects, assesses, plans and directs the maintenance tasks, while John Holland Rail provides the resources to implement the task.

The ambient temperature was relatively high, sleepers had recently been replaced and track tamping had occurred that morning. However, WestNet Rail's COP does not specifically document requirements to address the potential effect of maintenance on track stability, especially when such maintenance is conducted in high ambient temperatures.

As previously described, high temperature alone is generally not the primary cause of a misalignment. Properly constructed and maintained track should not misalign in the normal range of operating temperatures, or for that matter, temperatures that slightly exceed the designed safe operating temperature. There are other factors that contribute to a misalignment, such as:

- uncorrected rail creep
- uneven rail stresses at fixed or bunching points
- reduced resistance against lateral movement due to track maintenance or inadequate ballast profile.

Neither WestNet Rail nor John Holland Rail had documented procedures to manage these factors in relation to track maintenance on the DIRN.

For example, WestNet Rail's COP recognises that track tamping increases the risk of lateral misalignment or buckling due to a reduction in track lateral resistance. However, while the COP offers speed restriction as a strategy to control this risk, it qualifies this strategy with "...if deemed to be appropriate." The COP provides no criteria by which to assess appropriateness, nor is there any guide as to what speed restriction is to apply, for what period, or what criteria is to be achieved to permit removal of the speed restriction.

Similarly, John Holland Rail's process procedures do not address the potential reduction in track lateral stability due to track maintenance. For example, 'Track Machine Re-surfacing' (document number R057/RES) provides clear procedures for conducting the task, but offers no strategy to control the potential risk to track stability if the maintenance function is conducted in high ambient temperatures.

3.4.7 Summary of Standards and Procedures

Koolyanobbing

Analysis of standards and procedures identified the following observations relating to a misalignment developing within the turn-out at Koolyanobbing:

- There was no suggestion that scheduled track patrols were deficient in their task of monitoring the track as required by WestNet Rail's COP.
- WestNet Rail did not consider the Koolyanobbing area a hazard location susceptible to lateral instability. Therefore occurrences of high ambient temperature were not trigger events for unscheduled inspections.
- Replacement of timber sleepers ten days before the derailment of 6MP4 and subsequent track tamping on the day of derailment, reduced the track structure's resistance against lateral movement.
- Procedures do not exist that clearly document the requirements for track maintenance with consideration to the affect the maintenance may have on track stability, especially when this maintenance function is conducted in high ambient temperatures.
- While not formally documented, WestNet Rail has implemented an informal process to manage the potential risk to safe rail operations due to high temperatures.

- While the ambient air temperature came close to 40°C on the day of the two derailments, it did not actually exceed 40°C. Consequently, HSR were not applied over the track sections supported on concrete sleepers.
- For the purposes of HSR, WestNet Rail defined the track at Koolyanobbing as supported on concrete sleepers, even though approximately 200 metres of track was supported on timber sleepers.
- The 200 metre section of timber sleepere track was less able to resist temperature induced rail stresses than if it had been supported on concrete sleepers. Considering it is likely that the track structure had been disturbed due to track tamping, the application of HSR over this section of track may have been appropriate.

Booraan

Analysis of standards and procedures identified the following observations relating to a misalignment developing at Booraan:

- A minor alignment defect was detected approximately 20 metres before the level crossing at Booraan. This defect was repaired eight days before the derailment of 6SP5; however, it was not assessed as being a potential warning sign that track stability may be a problem in the area.
- There was no suggestion that scheduled track patrols were deficient in their task of monitoring the track as required by WestNet Rail's COP. However, there remains the opportunity to improve the assessment of patrol observations. Irrespective of an area being considered as resistant to lateral and longitudinal rail movement, assessment should consider that a minor track defect may be a warning sign of undetected track instability.
- WestNet Rail did not consider the Booraan area a hazard location susceptible to lateral instability. Therefore occurrences of high ambient temperature were not trigger events for unscheduled inspections.
- No track maintenance work had been conducted recently that may have reduced the track lateral stability.
- No procedures were in place to monitor or detect longitudinal rail movement. While well restrained concrete sleepere track may not be prone to longitudinal rail movement, only through rail creep monitoring is it possible to verify if the track structure is at risk of misalignment due to longitudinal rail movement.
- While not formally documented, WestNet Rail has implemented an informal process to manage the potential risk to safe rail operations due to high temperatures.
- While the ambient air temperature came close to 40°C on the day of the two derailments, it did not actually exceed 40°C. Consequently, HSR were not applied over the track sections supported on concrete sleepers.

3.5 Accident Response

Accidents, by their very nature are unpredictable, and rarely will the sequence of events be common across each accident. Therefore, it is important that an

organisation develop and implement an accident response plan that details the generic process required to manage a broad range of accident scenarios.

Track owners and rail operators are required, as part of their accreditation, to “...*establish and maintain detailed procedures...*”²⁰ for major incident management. These procedures are required to include:

- initial response procedures
- call-out procedures
- on-site management of the incident
- liaison with emergency services, and
- initiation of investigation.

Since an accident usually involves more than one organisation, it is essential that an accident response plan complements the equivalent plan of other organisations. To achieve this, the accident response plan of the track owner or access provider will generally be the governing document, with access agreements documenting the general obligations of both the track owner and the rail operator. Ultimately, successful response to an accident requires the coordination and cooperation of all involved parties.

3.5.1 Procedures

The standard access agreement between WestNet Rail and its rail operator customers addresses accident response. The access agreement requires WestNet Rail to develop and implement an accident response plan in “...*consultation with the Operator...*” Similarly, the operator is required to develop and implement an accident response plan which is “...*consistent with any plan prepared by WestNet...*”

WestNet Rail’s documented procedure used to guide the response to the derailments is the *Procedure for the Management of Mainline Emergencies*²¹.

Pacific National’s documented procedure used to guide the response to the derailments is the procedure *Incident Response and Site Management*²².

Initial response procedures

Generally, the initial response procedure involves immediate notification of the accident to the train controller. The train controller then coordinates further response until the appropriate incident manager adopts this role. Following the initial notification, the primary role of on-site personnel is to ensure the site is protected against further safety hazards.

For the derailments at Kooyanobbing and Booraan, the locomotive drivers’ response was consistent with the process described above, and consistent with Pacific National’s procedure. While the train controller’s response was consistent

20 AS4292.1-1995 “Railway safety management, Part 1: General and interstate requirements”

21 Document Number W110-200-019, Revision 3.00, 11/01/05

22 Document Number SHE-001, Revision R01, 29/10/03

with the process described above, this process is not fully documented in WestNet Rail's procedure. The process in WestNet Rail's procedure begins with the required actions of the train controller following the notification and does not document the process required of on-site personnel. It should be recognised that on-site personnel may be members of the public, employees of WestNet Rail, the rail operator, or the maintenance provider.

Call-out procedures

Generally, the call-out procedure involves notification of the accident to senior members of each organisation, and emergency services if required.

For the derailments at Koolyanobbing and Booraan, the response was consistent with the process described above, and consistent with WestNet Rail's and Pacific National's respective procedures.

On-site management of the incident

Generally, the accident site is initially managed by on-site personnel until a nominated site coordinator arrives on-site. Unless injured, this initial role will usually be filled by the locomotive drivers. The nominated site coordinator will usually be an employee of the track owner; however, for more serious accidents an emergency services officer or police officer may adopt this role.

For the derailments at Koolyanobbing and Booraan, the locomotive drivers' response was consistent with the process described above, and consistent with Pacific National's procedure. While WestNet Rail's response was consistent with the process described above, this process is not fully documented in WestNet Rail's procedure. WestNet Rail's procedure does not allow for an employee to be nominated as the site coordinator, relying solely on a "...*Senior Fire Services Officer or Police Officer...*" to take on this function.

Liaison with emergency services

Generally, the train controller will notify emergency services. The train controller will continue to liaise with emergency services until a nominated site coordinator adopts this responsibility. If the nominated site coordinator has not arrived, the locomotive drivers or other on-site personnel will usually liaise with on-site emergency services.

For the derailments at Koolyanobbing and Booraan, the response was consistent with the process described above, and generally consistent with WestNet Rail's and Pacific National's respective procedures.

Initiation of investigation

The investigation into a rail accident will usually be the responsibility of the track owner or access manager unless an independent investigation is to be conducted. The primary aim of the investigation is to identify the causal factors that contributed to the accident. The aim is also to identify safety measures to help prevent recurrence. A key component of this process is the gathering of physical evidence before it is disturbed by the recovery process.

For the derailments at Koolyanobbing and Booraan, an independent investigation was initiated. However, it is still important for an organisation to recognise the requirements of the investigation, irrespective of the organisation conducting the investigation.

WestNet Rail's procedure for accident response makes no reference to the requirement for investigation. However, it does state that restoration may proceed once the "*...area has been declared safe.*" This presents the risk that any evidence is likely to be destroyed before it can be gathered by the investigation. The likelihood of this occurring was demonstrated at Booraan where restoration works had started before evidence gathering, by WestNet Rail representatives, could begin.

WestNet Rail does have a documented procedure for investigation²³. While this document states "*...the site cannot be interfered with until a determination on any investigation requirements have been made*" there is no referenced link between this document and the accident response procedure. In conflict with the investigation procedure, the accident response procedure states that restoration may proceed once the "*...area has been declared safe*".

3.5.2 Site Restoration

A documented process for site restoration is not a specific requirement of accreditation; however, it is still an important issue relating to an accident. 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, as previously described, the investigation and identification of safety measures to help prevent a future recurrence of the accident is also important.

To achieve an appropriate outcome, the investigation should not delay prompt recovery work for any longer than is absolutely necessary. Importantly the recovery work should not contaminate essential evidence required for the investigation. Gathering of evidence requires not only site inspection before site restoration, but restoration in a manner that prevents further damage to rail equipment. This allows closer examination of equipment after site restoration.

Site restoration at both Koolyanobbing and Booraan had the potential to compromise an accident investigation. At Koolyanobbing, the methods used for site recovery increased the risk of evidence contamination, possibly preventing effective off-site examination. While at Booraan, the recovery process almost prevented the initial site inspection and gathering of evidence.

The opportunity exists for WestNet Rail, its contractors and operational customers to improve coordination of investigation and site restoration processes.

23 Document Number W110-200-018, Revision 1.06, 01/04/04 "Procedure for Advice, Investigation and Implementing Recommendations Following Derailments / Incidents"

3.5.3 Summary of Accident Response

It should be recognised that any accident requires sufficient resources to manage an effectively response. However, the resource capabilities are likely to be stretched when two significant derailments occur within one hour and 200km of each other, especially when the same organisations are associated with both derailments.

Considering the difficult circumstances, the actions of drivers, train control staff, and emergency services was generally conducted in an efficient and professional manner. However, the investigation identified opportunities to improve documented procedures, and coordination of investigation and site restoration processes.

The key to effective response, investigation and restoration is cooperation between all involved parties. The level of cooperation should begin before any accident, with the development and preparation of procedures and subsequently ensuring all parties are familiar with their responsibilities.

As previously described, the principal document for accident management will usually be the track owners (or access provider), in this case WestNet Rail. Therefore, WestNet Rail's documented procedures should take a 'whole of incident' approach; clearly document the obligations and requirements of all involved parties, not only those of WestNet Rail personnel. Similarly, the procedure should be generic such that all levels of accident are relevant. For example, police or emergency services personnel are only likely to take on the role of site coordination depending on the nature or magnitude of the accident. It is more likely that initial site coordination will be managed by the train crew until a WestNet Rail nominated coordinator arrives on-site.

The procedures should also address investigation and site restoration issues. Again, cooperation is the key to effective site restoration while preserving evidence for accident investigation.

3.6 Alternative Derailment Mechanisms

Considering how unusual it is for two similar derailments to occur approximately an hour apart and within 200 kilometres of each other, the investigation team committed significant resources into analysis of alternative derailment mechanisms. Also, following their review of the ATSB draft report, WestNet Rail's submission expressed strong opinion that freight loading, train handling, or a rollingstock defect may have contributed either directly to one or both derailments, or may have contributed to the development of a track defect subsequently causing one or both derailments.

3.6.1 Pacific National train 6MP4 – Derailed at Koolyanobbing

No evidence was found to suggest that the sole cause to the derailment at Koolyanobbing was related to freight loading on train 6MP4, train handling of train 6MP4, or a rollingstock defect within train 6MP4. As previously described, site evidence, locomotive data logs, driver reports and injuries sustained by the second driver indicate that train 6MP4 encountered a track misalignment and subsequently derailed. The same evidence and analysis indicates that it is unlikely that freight loading, train handling or a rollingstock defect on train 6MP4 could have contributed to the development of a misalignment at Koolyanobbing.

Only freight loading, train handling, or a rollingstock defect of a previous train could possibly have contributed to the development of a track defect at Koolyanobbing. Train 6SP5, which subsequently derailed at Booraan, was the only train to have passed through Koolyanobbing before train 6MP4 and after the completion of track maintenance that morning. Analysis of train 6SP5 is summarised in the following section.

3.6.2 Pacific National train 6SP5 – Derailed at Booraan

Train 6SP5 passed through Koolyanobbing after the completion of track maintenance that morning and the drivers did not observe any form of misalignment. Approximately 75 minutes later the following train 6MP4 apparently encountered a misalignment and consequently derailed. Just over an hour after 6MP4 derailed, train 6SP5 derailed at Booraan.

Train 6SP5 at Koolyanobbing

For a train defect to cause a track misalignment, train loading, or train handling, or a defect or defects in rollingstock would have to be sufficient to cause an excessive lateral force.

If train 6SP5 exhibited any form of undesirable loading or defect, inappropriate train handling could have caused excessive lateral forces to be transmitted to the track structure. However, there was no evidence to suggest any inappropriate train handling through Koolyanobbing by the driver of train 6SP5. The locomotive data log for train 6SP5 indicated that the train was slowly accelerating between 101 km/h and 105 km/h and showed no brake application. Under these conditions the train would be stretched and unlikely to have exerted excessive forces onto the track structure.

Evidence indicates a significant impact with a check-rail²⁴ at the Koolyanobbing turnout such that the leading edge of the check-rail was fractured. It is unlikely that any hanging brake equipment would have resulted in this fracture. This scenario would require this rollingstock defect to result in the subsequent derailment at Booraan where no track structure component existed to be impacted.

The investigation team also considered any possible impact on the check-rail at Koolyanobbing from wheels which had moved off their normal seating position near the end of their respective axles (wheel seats). For a wheel to strike the leading edge of a check-rail, a wheel-set would have to exhibit a reduced back-to-back flange measurement of at least 120mm.

Of the three wagons from 6SP5 which were quarantined at Booraan for further examination, two wheels on two separate wheel-sets had moved off their normal seating position. None of the relevant wheels exhibited any evidence of a wheel impact that had subsequently travelled 160km before derailed at Booraan. Similarly, had a wheel-set exhibited a reduced back-to-back flange measurement at Koolyanobbing, it would subsequently have impacted with other track

²⁴ A check-rail consists of a length of rail fixed to the sleepers inside the running rail. An 80mm flare at the leading edge of the check-rail is designed to guide the wheel flange through a 45mm gap between the running rail and the check-rail and subsequently guide the wheel the correct direction through the points.

infrastructure in the 160km it travelled to Booraan. There was no reported impact with track infrastructure at any of the turn-outs (at least 15) between the derailment site at Koolyanobbing and the derailment site at Booraan. As previously discussed, the most likely cause for the movement of the wheels was an impact during the derailment of 6SP5. Consequently, it was considered extremely unlikely that a wheel on 6SP5 could have exhibited a reduced back-to-back flange measurement sufficient to have impacted with the check-rail at Koolyanobbing.

The fractured check-rail and the damaged infrastructure in the immediate vicinity the mechanism of fracture was carefully considered. A significant number of flange marks were evident indicating that a number of wheels had derailed over the check-rail (Refer to figure 16). It is also evident that at least one bogie had derailed before the check-rail and travelled past the check-rail while derailed to the right (Refer to figure 17). Considering the number of derailed wheels passing over the check-rail, and that at least one bogie had derailed before the check-rail, the most probable cause of the fractured check-rail is multiple wheel impacts during the derailment of train 6MP4.

Figure 16: Fractured check-rail showing wheel derailment markings

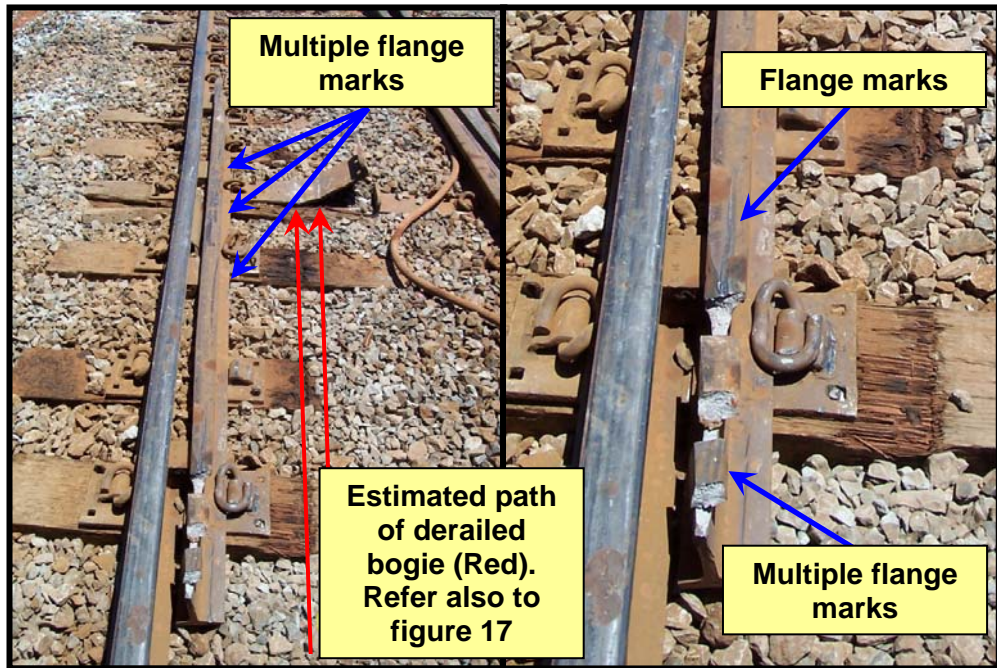
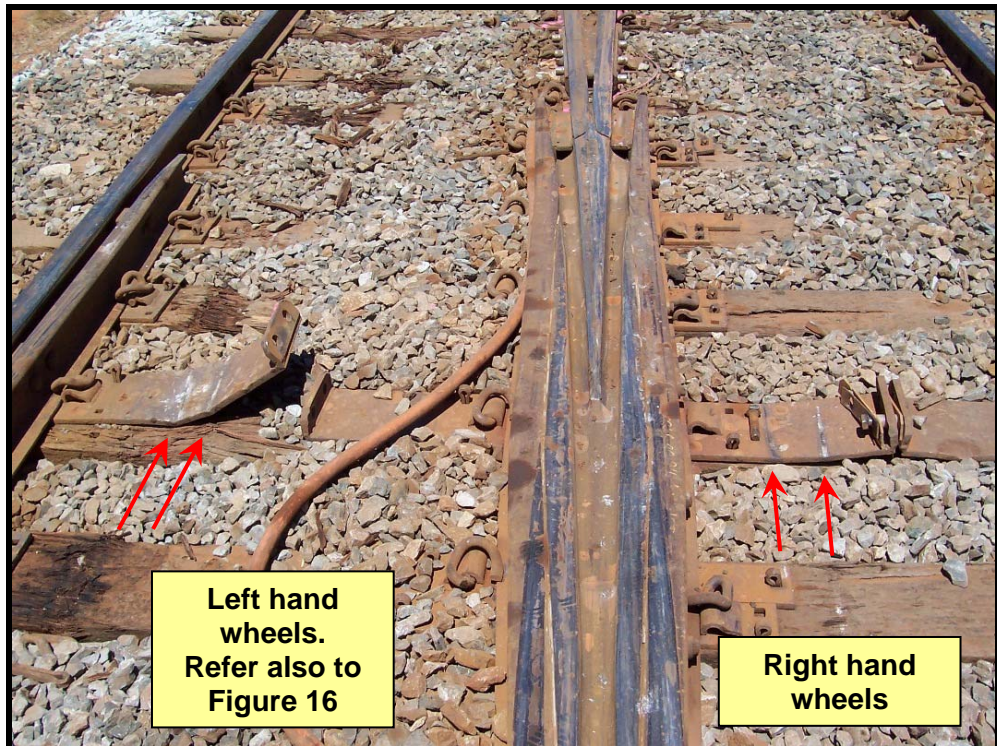


Figure 17: Estimated path of derailed bogie past the fractured check-rail



Photos (Figures 16 and 17) by WestNet Rail

The investigation team also considered the possibility that freight loading and wagon behaviour may have contributed to the development the misalignment at Koolyanobbing and subsequently caused the misalignment and derailment at Booraan. Analysis of freight loading and wagon behaviour of train 6SP5 is discussed in the following section. While it is recognised that train 6SP5 would have exerted a lateral force onto the track structure, there was no evidence to suggest that these forces were either excessive or sufficient to cause a stable track structure to shift laterally.

Train 6SP5 at Booraan

A number of train behaviour related scenarios were considered and analysed to determine a possible cause for the derailment of 6SP5 at Booraan.

- Inappropriate train handling (discussed in section 3.2.3)
- Inappropriate loading of freight wagons
- A rollingstock defect resulting in a flange climb derailment
- A rollingstock defect resulting in a gauge spread derailment
- Excessive lateral force contributing to a track misalignment.

Derailment site evidence indicated that two derailed wagons travelled over the road crossing at Booraan, RQSY34494 and RRAY7175. The trailing bogie of RQSY34494, while dislodged from its centre plate, remained under the wagon body and was derailed to the right (in direction of travel). The lead bogie of RRAY7175 was derailed to the left, while all other bogies of RRAY7175 were dislodged from under the wagon body and remained on the Kalgoorlie side of the crossing. The 5-

pack RRAY wagon, with only its lead bogie under the body, was dragged along the left hand ballast shoulder.

Figure 18: Wheel flange markings at road crossing

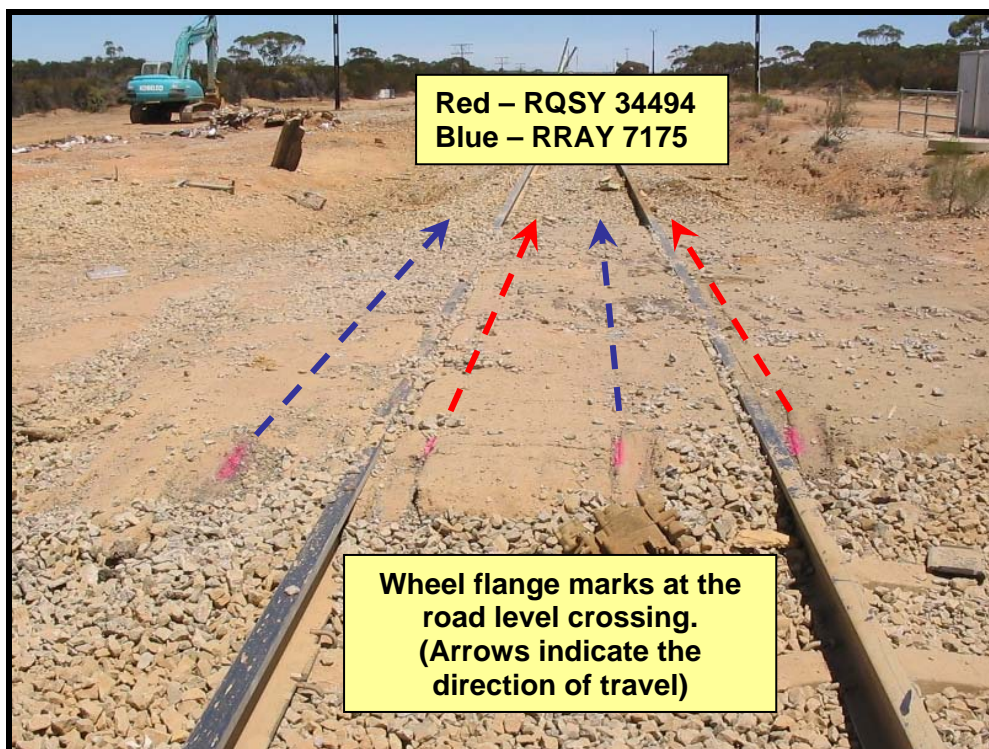


Photo by WestNet Rail

A measure of a wagon's likelihood of derailment due to flange climb is generally expressed in terms of the ratio between lateral force and vertical force (L/V ratio). As lateral force increases and/or vertical force decreases, the likelihood of derailment increases. Among other elements, lateral force is affected by train handling and rollingstock behaviour such as bogie hunting or steering problems. Vertical force is primarily affected by the mass supported by each wheel-set.

A flange climb derailment will usually leave evidence in the form of markings where the wheel flange has rolled over the rail head. When 6SP5 derailed at Booraan, the progressive derailment of freight wagons caused significant damage to the track. Consequently, no conclusive evidence could be found to support a contention that the derailment of 6SP5 was due to simple flange climb. However, the evidence obtained does shed some doubt on the theory that simple flange climb caused the derailment of 6SP5. If more than one bogie derails due to flange climb, the most common sequence of events is for the second and subsequent bogies to follow the first and derail in a similar direction. This is due to the first derailed bogie transferring lateral forces through wagon bodies and couplers such that the lateral forces exerted by following bogies act in the same direction. However, in this derailment the first two derailed bogies have derailed towards opposite sides of the track. Consequently, it is unlikely that the derailment of 6SP5 at Booraan was caused by a rollingstock defect resulting in simple flange climb.

It was evident that, at some point, the body of wagon RQSY34494 had lifted and allowed the rear bogie to become dislodged from its centre plate. Observation also indicated that the load on wagon RQSY34494 was positioned over the front two

thirds of the wagon, potentially exhibiting an undesirable load differential between adjacent bogies on a single wagon body. However, in track load measurement²⁵ indicated that the load distribution was approximately 55% on the lead bogie and 45% on the trailing bogie with a load differential of approximately four tonnes. This was well within the 20 tonne differential limit specified in Pacific National's "Train Inspection Manual". Notwithstanding this, it is still possible for inappropriate train handling accompanied with large trailing loads to induce wheel unloading or body lift.

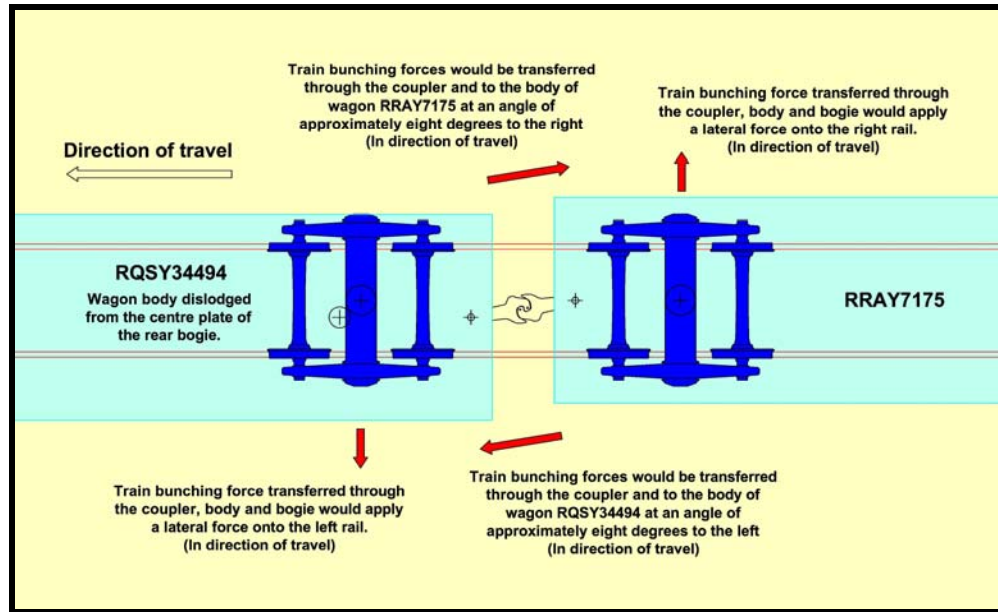
There was approximately 2800 tonnes of train trailing wagon RQSY34494. While this is not considered excessive, under extreme conditions wheel or body lift could occur. This would normally involve heavy dynamic braking on steep descending gradients. No evidence was found to suggest any inappropriate handling of train 6SP5. However, the investigation team conducted some analysis to determine the likelihood that the rear bogie of wagon RQSY34494 may have become dislodged before the derailment site.

Assuming no track defect, significant lateral force would be required to allow a wheel flange to climb and derail, or to cause the track to fail and subsequently derail the train. The body of wagon RQSY34494 was observed to have been displaced to the left of its normal position, resulting in a coupler angle between itself and the following wagon of approximately eight degrees. The angled coupler would allow any longitudinal train forces, caused by train bunching or stretching, to transfer through the bogies and apply a lateral force onto the track structure. Train 6SP5 was travelling at approximately 97km/h and was in the process of braking when it began to derail. Under these conditions it is more likely that excessive bunching forces, not stretching forces, would produce sufficient lateral force to cause derailment.

Figure 19 illustrates the direction of lateral forces, had bunching forces been applied to the dislodged body on wagon RQSY34494. If the lateral forces were sufficient to cause wheel flanges to climb, the most likely direction of derailment would be for the rear bogie of wagon RQSY34494 to derail to the left and the lead bogie of RRAY7175 to derail to the right. However, the evidence indicates that the opposite occurred.

²⁵ Measurements sourced from the Australian Rail Track Corporation.

Figure 19: Lateral forces due to train bunching and coupler angle



Similarly, if the lateral forces were sufficient to cause the track to fail (for example spread gauge), the rear bogie of RQSY34494 would exert force on the left rail and the lead bogie of RRAY7175 would exert force on the right rail. A spread gauge derailment usually results in wheels falling between the left and right rails. However, as previously mentioned, the first two derailed bogies have derailed towards opposite sides of the track.

Alternatively, the spreading forces may cause the failure of rail fastenings thereby allowing the rail to roll outwards. While the rear bogie of RQSY34994 did exhibit significant wear to wheel flanges on the left side, examination of the wheel flanges and the relevant wagon body found that the worn flanges were consistent with rubbing on the wagon body. However, if some of the wear was a result of wheels running over rail that had rolled outwards, it is reasonable to assume that the rail to have rolled was the left rail.

If the rear bogie of RQSY34494 travelled over rail that had rolled outwards, its right side wheels would most likely fall between the two rails and run along the sleepers. The right side wheels would then be restrained by the right rail and prevented from moving to the right. The wheels of the following bogie would most likely follow in the same way. However, as stated above, by the time RQSY34494 traversed the road crossing, it is evident the opposite had occurred. The left wheels of the rear bogie had fallen between the rails and the right wheels were running outside the right rail. The lead bogie of RRAY7175 did not follow in the same manner, but derailed to the left.

The investigation team also analysed markings found on the running face of the left rail. These markings were consistent with a wheel rubbing or grinding against its running face as would be expected during a gauge spread derailment. It is evident that at some point during the derailment, the repeated impact of derailed wheels damaged the concrete sleepers to an extent where they were unable to hold the rails and retain gauge. After this occurred, the following wheels would likely fall between the rails subsequently allowing one of more wheels to rub or grind along the rails running face. However, over 100 wheel-sets derailed at Booraan and it is

unlikely that any one wheel could be identified as the cause of the rail damage. Similarly, it is unlikely that the markings on the running face of the left rail could be conclusively attributed to any wheels of the first few bogies derailed at Booraan.

Figure 20: Damaged sleepers and spread gauge



Photo by WestNet Rail

Considering the direction of derailment for the rear bogie of wagon RQSY34494 and the leading bogie of RRAY7175, it is considered unlikely that a dislodged rear bogie of wagon RQSY34494 contributed to the derailment of train 6SP5. It is more likely that the bogie dislodged as a consequence of the derailment, possibly as the bogie struck the bitumen road crossing.

Most of the analysis in this alternative scenario assumes that the rear bogie of RQSY34494 was the first to derail. While it is possible for a derailed bogie to cause the derailment of a bogie in front, the most likely direction of derailment would again be in the same direction as the original derailed bogie not in opposite directions as evident in this derailment. Again, this is due to the first derailed bogie transferring lateral forces through wagon bodies and couplers such that the lateral forces act in the same direction.

3.6.3 Summary of Alternative Derailment Mechanisms

There was no evidence or indication of any fault, defect or deficiency in freight loading, train handling, or rollingstock that may have directly contributed to one or both derailments. Similarly there was no evidence or indication of any fault, defect or deficiency in freight loading, train handling, or rollingstock that may have contributed to the development of a track defect subsequently causing one or both derailments.

3.7 Previous Accidents

There were no records of similar accidents occurring under similar circumstances on the DIRN section managed by WestNet Rail. Similarly, a search and review of previous accident investigations in other jurisdictions did not find any recent events that completely replicated the nature and geographic features that existed at Koolyanobbing and Booraan.

Considering the lack of similar accidents, the search and review extended to recorded track misalignments that did not result in an accident. This search identified that misalignment or buckling of 60kg/m rail supported on concrete sleepers, although rare, has occurred elsewhere in Australia. For example, over the past 10 years in New South Wales, 11 misalignments were recorded for 60kg/m rail supported on concrete sleepers with one misalignment recorded for 53kg/m rail supported on concrete sleepers.

The search and review of previous accident investigations and recorded track misalignments elsewhere in Australia confirmed that high temperature alone was generally not the primary cause of a misalignment. Factors such as uncorrected rail creep, uneven rail stresses at fixed or bunching points, reduced resistance against lateral movement due to track maintenance or inadequate ballast profile usually contributed to the development of a track misalignment.

4

CONCLUSIONS

At approximately 1500 on 30 January 2005, Pacific National freight train 6MP4 derailed at Koolyanobbing, approximately 200 kilometres west of Kalgoorlie, Western Australia. On the same day at approximately 1605, Pacific National freight train 6SP5 derailed near Booraan, approximately 360 kilometres west of Kalgoorlie.

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

4.1 Probable Causal Factor of Derailment

At both Koolyanobbing and Booraan, the most probable cause for the derailment of freight train 6MP4 and train 6SP5 was track misalignment on a very hot day in the form of a buckle, exacerbated by the passage of locomotives and rolling stock.

4.2 Contributing Factors

Koolyanobbing

The investigation determined that a number of factors combined to contribute to the derailment of freight train 6MP4 at Koolyanobbing, any one of which may not have resulted in a derailment in its own right.

1. It is likely that the timber sleepers replaced ten days before the derailment of 6MP4, exhibited a reduced friction bond with the ballast due to a lower degree of particle penetration. While rail traffic may have increased ballast consolidation, it is unlikely that maximum lateral resistance would have been achieved.
2. It is likely that a reduced friction bond due to replacement sleepers, compounded by track tamping on the morning of the derailment, contributed to reduced resistance against lateral movement.
3. Compressive longitudinal forces existed within the rail due to a recorded rail temperature approximately 18°C higher than the design neutral temperature of 40°C.
4. It is likely that the lateral forces exerted by the passage of freight train 6SP5, approximately 75 minutes before the derailment of 6MP4, further reduced the track's resistance against lateral movement. If the track structure weakened sufficiently to allow lateral movement, it is likely that a misalignment would have developed under train 6SP5. However, the misalignment would not have been of sufficient magnitude to derail train 6SP5, and was unlikely to have been detectable by the driver of 6SP5.
5. Initially the misalignment was not of sufficient magnitude to immediately derail 6MP4, allowing approximately 200 metres of train to traverse the misalignment. However, the misalignment caused severe lateral movement of the rail vehicles which further increased the misalignment until wagons ultimately derailed.

Booraan

The investigation determined that a number of factors combined to contribute to the derailment of freight train 6SP5 at Booraan, any one of which may not have resulted in a derailment in its own right.

1. Even though the track structure design at Booraan may be resistant to longitudinal rail movement, longitudinal rail movement may have occurred over a period of time.
2. The level crossing and slight descending gradient had the potential to create a bunching effect in the track immediately before the level crossing, lowering the effective neutral temperature. The lower neutral temperature increased the influence of thermal expansion such that the forces applied to the track structure also increased.
3. Compressive longitudinal forces existed within the rail due to a recorded rail temperature approximately 21°C higher than the design neutral temperature of 40°C.
4. It is likely that the lateral forces exerted by the passage of freight train 1PS6, approximately two hours before the derailment of 6SP5, further reduced the track's resistance against lateral movement. If the track structure weakened sufficiently to allow lateral movement, it is likely that a misalignment would have developed under train 1PS6. However, the misalignment would not have been of sufficient magnitude to derail train 1PS6, and was unlikely to have been detectable by the driver of 1PS6.
5. Initially the misalignment was not of sufficient magnitude to immediately derail 6SP5, allowing approximately 600 metres of train to traverse the misalignment. However, the misalignment progressively increased lateral movement of rail vehicles, further increasing the misalignment until wagons ultimately derailed.

4.3 Other Findings

The following findings are common to both the derailment of 6MP4 at Koolyanobbing and of 6SP5 at Booraan. The findings may not have directly contributed to either of the derailments but they are documented with the intention that further opportunities for improvement to operational railway safety may be identified.

1. There was no suggestion that scheduled track patrols were deficient in their task of monitoring the track as required by WestNet Rail's COP.
2. While the ambient air temperature came close to 40°C on the day of the derailment, it did not actually exceed 40°C. Consequently, heat speed restrictions were not applied over the track sections supported on concrete sleepers.
3. While not formally documented, WestNet has implemented an informal process to manage the potential risk to safe rail operations due to high temperatures.
4. There was no rollingstock defect identified that could be considered as causing or contributing to either derailment. Similarly, there was no deficiency in rollingstock maintenance practices or procedures that could be considered as contributing to either derailment.

5. WestNet Rail did not consider the Koolyanobbing nor Booraan areas to be hazard locations susceptible to lateral instability. Therefore occurrences of high ambient temperature were not trigger events for unscheduled inspections.

Koolyanobbing

The following findings may not have directly contributed to the derailment of 6MP4 at Koolyanobbing. However they are documented with the intention that further opportunities for improvement to operational railway safety may be identified.

1. It is possible that longitudinal rail movement may have occurred over time, even though the track structure design at Koolyanobbing may be resistant to longitudinal rail movement.
2. It is possible that the turnout and adjacent level crossing accompanied by a slight descending gradient would encourage compressive forces within the rail, effectively lowering the rail neutral temperature at this location. A lower neutral temperature would have increased the influence of thermal expansion such that the forces applied to the track structure also increased.
3. Procedures do not exist that clearly document the requirements for track maintenance with consideration to the affect the maintenance may have on track stability, especially when this maintenance function is conducted in high ambient temperatures.
4. For the purposes of HSR, WestNet Rail defined the track at Koolyanobbing as supported on concrete sleepers, even though approximately 200 metres of track was supported on timber sleepers.
5. The 200 metre section of timber sleepereed track was less able to resist temperature induced rail stresses than if it had been supported on concrete sleepers. Considering it is likely that the track structure had been disturbed by track tamping, the application of HSR over this section of track may have been appropriate.
6. While site restoration did not start until after site inspection and gathering of on-site evidence had been completed, reports indicated that the methods used for site recovery may not have been appropriate to prevent further damage to rollingstock. The recovery process presented an increased risk of evidence contamination.

Booraan

The following findings may not have directly contributed to the derailment of 6SP5 at Booraan. However they are documented with the intention that further opportunities for improvement to operational railway safety may be identified.

1. There had been no track maintenance work conducted recently that may have reduced the track lateral stability.
2. It is likely that a minor alignment defect repaired eight days before the derailment of 6SP5 may have indicated a potential track stability problem at the Booraan derailment site.
3. It is likely that the track structure demonstrated a reduced resistance to lateral movement due to a deficient ballast shoulder profile in some areas.

4. It is possible that periodic track maintenance work may have encouraged a redistribution of longitudinal rail forces. For example, two months before the derailment of 6SP5, track tamping was conducted while travelling on the downhill gradient towards the level crossing. The most likely result would be slight rail creep in the direction of travel.
5. It is possible that a period of reduced track stability would follow any tamping work, during which time the dynamic forces applied by train operations may also result in slight rail creep towards the level crossing.
6. No procedures were in place to monitor or detect longitudinal rail movement.
7. The existing procedures for track recovery following a derailment do not properly provide for the collection and preservation of evidence. As a result there was a potential risk of losing evidence.

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 Recommendations

RR20060027

The ATSB recommends that WestNet Rail develop, document and implement procedures for managing reduced track stability due to track maintenance. The procedures should give consideration to:

- The effect that maintenance may have on track stability, especially when conducted during periods of high ambient temperatures.
- The period of time that the track is likely to exhibit reduced stability and the effect of high ambient temperatures during this period.
- The application of speed limits following track maintenance work that may reduce track lateral stability.

RR20060028

The ATSB recommends that WestNet Rail develop, document and implement procedures for monitoring and management of longitudinal rail movement on the defined interstate rail network. The procedures should give consideration to:

- Descending gradients and ‘fixed point’ locations, such as road level crossings, that may encourage rail bunching and a lowering of the rail’s effective neutral temperature.
- Measurement and correction of rail stress and rail neutral temperature if longitudinal rail movement is detected.

RR20060029

The ATSB recommends that WestNet Rail develop, document and implement procedures whereby minor defects, identified through scheduled inspections, are assessed to determine factors that may have contributed to the defect.

RR20060030

The ATSB recommends that WestNet Rail ensure a full ballast profile for the defined interstate rail network, especially at locations that exhibit an increased risk of longitudinal rail movement.

RR20060031

The ATSB recommends that WestNet Rail review and document the procedure for managing potential risks to safe rail operations during periods of high ambient temperature, including the process of managing heat speed restrictions.

RR20060032

The ATSB recommends that WestNet Rail and its operational customers develop, document and implement procedures that clearly define the responsibilities of each party involved in a rail accident. The procedures should take a 'whole of incident' approach and give consideration to:

- The role of the accident investigation to identify factors that may have contributed to the accident.
- The requirement that essential evidence required for the investigation is not contaminated.
- The understanding that the investigation should not unnecessarily delay prompt recovery work.
- The requirement that the procedure should be generic to all accidents.

RR20060033

The ATSB recommends that the Western 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) WestNet Rail
- b) Pacific National
- c) John Holland Rail Pty Ltd
- d) Western 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 incorporated into the body of this report where appropriate.

Two freight train derailments west of Kalgoorlie in January 2005

An ATSB investigation has found that high track temperatures, track stability and the movement of rolling stock led to derailments involving Train 6MP4 at Koolyanobbing WA and Train 6SP5 at Booraan WA on the afternoon of 30 January 2005.

Koolyanobbing and Booraan are respectively about 200 kilometres and 360 kilometres west of Kalgoorlie. Both freight trains had been travelling to Perth on the Defined Interstate Rail Network (DIRN), 6MP4 having started its journey in Melbourne and 6SP5 in Sydney.

There were no serious injuries due to either derailment but many wagons from each train sustained extensive damage.

The Australian Transport Safety Bureau investigation determined that the most probable cause for each derailment was track misalignments in the form of track buckles on a very hot day. A number of additional factors combined to contribute to each derailment, any one of which may not have resulted in a derailment in its own right.

Considering how unusual it is for two similar derailments to occur approximately an hour apart and within 200 kilometres of each other, extensive examination and analysis of freight loading, train handling, and rollingstock was also conducted.

There was no evidence or indication of any fault, defect or deficiency in freight loading, train handling, or rollingstock that may have directly contributed to one or both derailments or to the development of a track defect subsequently causing one or both derailments.

In the interest of future safety the ATSB has made recommendations regarding management of track stability and movement, procedures for assessing minor defects and identifying factors that may have contributed to the defect, and documenting of procedures for managing safe operations during periods of high ambient temperature.