Report RO-2013-106:
Track occupation irregularity, leading to near head-on collision,
Otira-Arthur's Pass, 10 June 2013

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The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

Final Report

Rail inquiry RO-2013-106

Track occupation irregularity

leading to near head-on collision

Otira-Arthur's Pass

10 June 2013

Approved for publication: November 2014

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of the occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

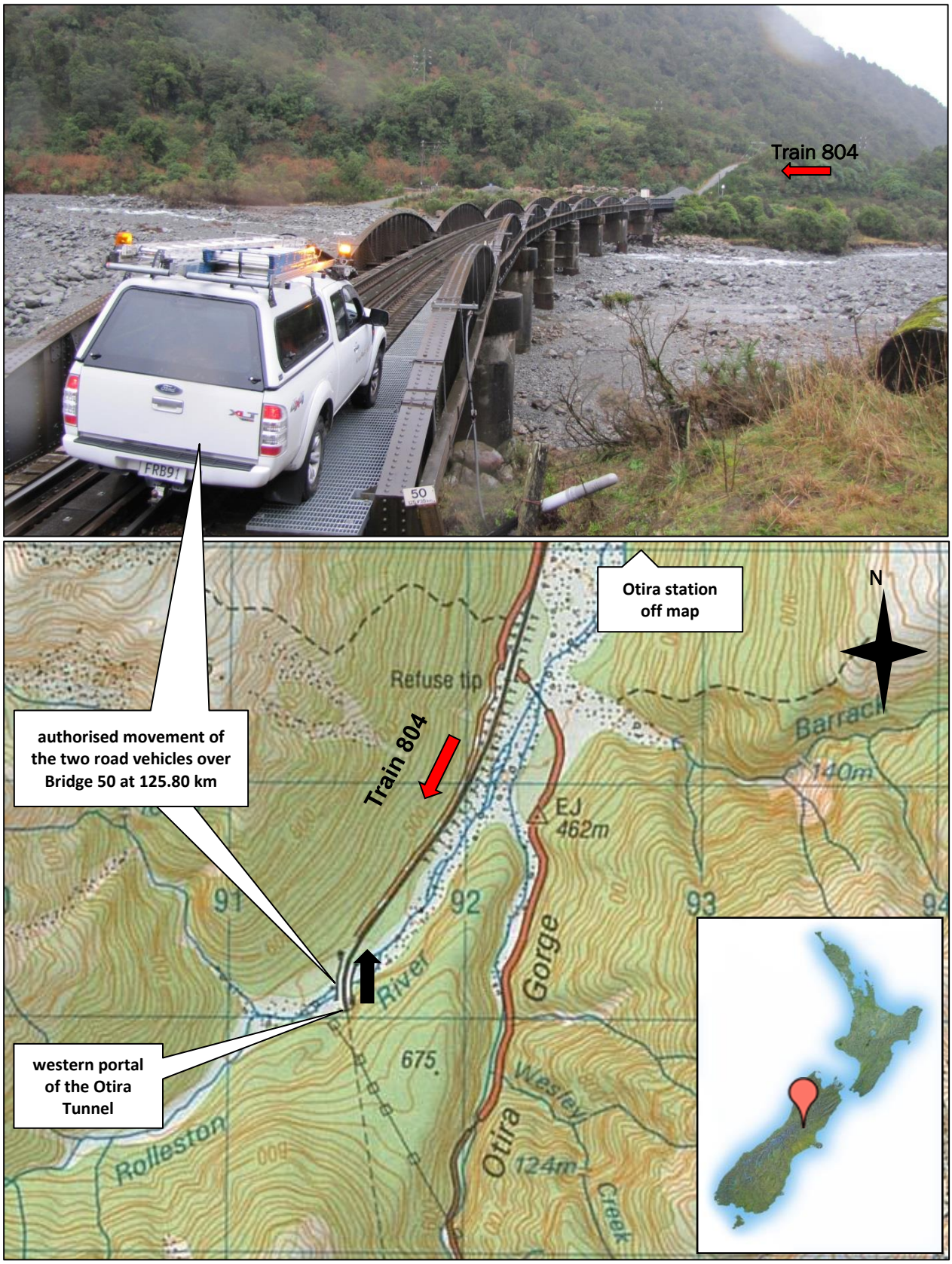
Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1980 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.



Opposing paths of the road vehicles and Train 804
between the Otira station and the western portal of the Otira Tunnel

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Abbreviations

Commission	Transport Accident Investigation Commission
km	kilometre(s)

Glossary

mimic screen	an electronic display in train control that shows the locations of trains on some sections of the controlled network
on-track	(in this instance) the process of positioning a road vehicle over the track so that it could be driven over rail Bridge 50
train control	the national train control centre located in Wellington
track occupation authorisation	an authority from train control for track maintenance staff to occupy a section of the controlled rail network to carry out inspections, repair work and other activities

Data summary

Train particulars

Type and number:	Tranz Alpine passenger Train 804
Origin/destination:	Greymouth-Christchurch, 231.06 kilometres (km)
Operator:	KiwiRail Limited
Maximum speed for area:	70 km per hour

Road vehicles

Details:	2010 Ford Ranger XLT, registration FRB91 2011 Ford Ranger utility, registration GBN519
Owner:	KiwiRail Infrastructure and Engineering

Incident details

Date and time:	10 June 2013, 1530 (NZ standard time)
Location:	Bridge 50 at the 125.80 km point between Otira and Arthur's Pass on KiwiRail's Midland Line, which runs between Rolleston (near Christchurch) and Greymouth
Persons on train:	train driver, on-board train staff and passengers
Persons in road vehicles:	one signals technician in each vehicle
Injuries:	nil
Damage:	nil

1. Executive summary

1.1. Summary of the incident

1.1.1. On the afternoon of 10 June 2013, KiwiRail's Tranz Alpine passenger train was travelling from Greymouth to Christchurch. The train departed from the Otira station on time, heading for the western portal of the Otira Tunnel. At about the same time, signals technicians had finished work on testing the tunnel door and ventilation systems at the western portal of the tunnel. About one minute after the train had departed from Otira, one of the signals technicians radioed train control and requested a track occupation authority to drive their two road vehicles across the rail bridge (Bridge 50) in the opposite direction from which the train was approaching.

1.1.2. The train controller assumed from the signals technician's request that the passenger train had already crossed Bridge 50 and entered the tunnel. Based on that assumption he gave them authority to cross the bridge, in the path of the approaching train.

1.1.3. The driver of the passenger train overheard the track occupation being authorised and realised that it conflicted with his train's movement. He reduced power and brought his train to a gradual stop before reaching Bridge 50, and alerted the train controller to the conflict.

1.1.4. The train controller had not followed KiwiRail's track occupation rules, which required him to verify the actual location of the train in the area before authorising the road vehicles to cross the bridge. He had three means at his disposal to verify where the train was located.

1.1.5. The Transport Accident Investigation Commission (Commission) found that the train controller's performance was highly likely to have been impaired by fatigue at the time of the incident. His fatigue was the effect of his shift roster in the weeks leading up to the incident, which did not allow him sufficient opportunity to obtain good quality sleep and recover adequately from sleep debt accumulated during his cycle of shifts.

1.1.6. The Commission identified two safety issues that contributed to the incident:

- the standard roster that the train controller was working in the weeks leading up to the incident did not offer him sufficient opportunity to recover adequately from sleep debt incurred after a shift cycle
- the train controller had been involved in three operating irregularities during the previous 16-months and KiwiRail had identified his having concentration and focus issues. Despite this KiwiRail had allowed him to continue in the train controller role.

1.1.7. The report refers to previous recommendations the Commission has made to KiwiRail and the NZ Transport Agency regarding train control rosters, fatigue and train controller wellbeing. The circumstances of this incident are relevant to both recommendations, and justify the Commission leaving them open until the safety issues identified in this report have been fully addressed.

1.1.8. The key lessons learnt from the inquiry into this occurrence were:

- it is important that train controllers do not make assumptions about the locations of trains when authorising track occupations, and do not use local or ad hoc practices to circumvent policies, procedures and rules designed to prevent accidents and incidents
- train control is a safety-critical function. If there is any doubt about a train controller's performance, they should be stood down until all doubt is removed
- the 24-hour train control roster should be designed to minimise and manage the risk of train controllers' performance being impaired by fatigue.

2. Conduct of the inquiry

2.1. On 11 June 2013 the NZ Transport Agency notified the Transport Accident Investigation Commission (Commission) of an incident that had occurred near Otira at about 1530 on 10 June 2013, under section 13(4) of the Railways Act 2005. The Commission opened an inquiry under section 13(1) of the Transport Accident Investigation Commission Act 1990, to determine the circumstances and causes of the incident, and appointed an investigator in charge.

2.2. The investigator interviewed:

- the train controller in Wellington on 12 June 2013
- the train control manager in Wellington on 18 June 2013 and again on 11 December 2013
- the train driver in Christchurch on 1 July 2013
- the signals technician from the lead vehicle in Greymouth on 2 July 2013.

He also travelled to Bridge 50 on 2 July 2013 to view the infrastructure that allowed KiwiRail's maintenance vehicles to travel over it without the need to use hi-rail equipment.

2.3. The investigator reviewed the data streams from the Tranzlog event recorder from the lead locomotive of the passenger train, the Otira-Arthur's Pass signalling system operated and displayed in train control, and the train control voice-recording system. The data was used to determine the sequence of events leading up to and during the incident.

2.4. The investigator also obtained a number of records and documents, including:

- the train controller's training records, his medical records (held by KiwiRail and his general medical practitioner), his work records, including the results of his various performance assessments, and his incident history in train control
- the train controller's roster and hours of work for the eight weeks leading up to the incident
- relevant KiwiRail policies and procedures
- the tunnel door display on the train controller's mimic screen.

2.5. On 2 August 2013 Dr Kay Cunningham, neuropsychologist/clinical psychologist, provided KiwiRail and the train controller with a neuropsychological report. The Commission obtained approval from the train controller for it to be supplied with a copy of the report.

2.6. On 7 April 2014 the Commission engaged the services of Dr T L Signal, Senior Research Director of the Sleep/Wake Research Centre at Massey University of New Zealand to advise of sleep/fatigue matters arising from the inquiries conducted into the shift rotations and rest breaks of, and the hours worked by, the train controller during the weeks preceding the incident.

2.7. The approach used by Dr Signal for analysing the information was based on that developed by the United States of American National Transportation Safety Board and the National Aeronautics and Space Administration-Ames Research Centre Fatigue Countermeasures Program, which focused on the physiological factors known to impair an individual's functioning. These physiological factors included:

- sleep-debt-induced fatigue
- the circadian biological clock
- shift working.

2.8. On 24 September 2014 the Commission approved the draft final report for circulation to interested persons for comment.

2.9. On 19 November 2014 the Commission considered submissions received from interested persons and made changes to the report where appropriate. The Commission approved the final report for publication on the same day.

3. Factual information

3.1. Narrative

3.1.1. On 10 June 2013 at 1448, a KiwiRail train controller started work and during the next three minutes he received a handover from the outgoing train controller detailing train and track occupation activities on the Midland and West Coast Lines. The handover included reference to testing of the tunnel door systems that was being carried out for the Otira railway tunnel.

3.1.2. The train control voice-recording system showed that the handover was completed by 1451 and the train controller was moderately busy for the 37-minute period up to 1528.

3.1.3. At 1528 the signalling system recorded that KiwiRail's Tranz Alpine passenger train (the train) had left the Otira station on time for the six-minute journey to the western portal of the Otira Tunnel. The train controller plotted its departure in red ink on the train control diagram, but he did not record the actual time in minutes as he was required to do.

3.1.4. One minute later at 1529, a signals technician who had been conducting the testing of the Otira Tunnel door systems radioed the train controller and requested 15 minutes of track occupation time for the work group's two road vehicles to travel over Bridge 50. The start point of the track occupation was about 50 metres from the western portal of the Otira Tunnel and the vehicles would be travelling across the bridge in the opposite direction to the train.

3.1.5. The audio recording from the train control workstation revealed that the train controller had not had to attend to any intervening radio calls from the time he updated the train control diagram with the train's departure from Otira to when he was responding to the signals technician's request.

3.1.6. During the authorisation process the train controller saw that the train was no longer at the Otira station when he looked at the signalling mimic screen (see Figure 1). The mimic screen included an additional display for a tunnel door operation at the western portal of the Otira Tunnel. The display used a crimson vertical marker that showed the door was open at the time the occupation was authorised. This meant that the train had not entered the tunnel and therefore had not passed over the bridge.

3.1.7. The train controller said that he concluded in his mind "that it had already passed over Bridge 50 and had proceeded to go through the adjacent [Otira] tunnel". The occupation was authorised at 1530.

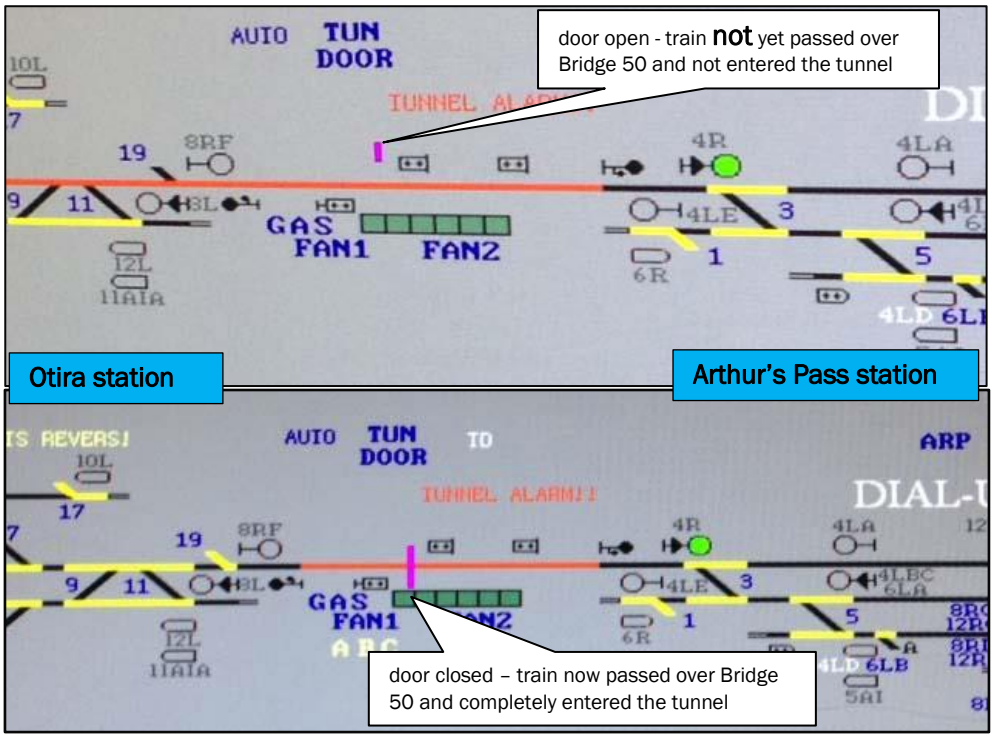

Figure 1
Train control mimic screen displays with a train moving from Otira to Arthur's Pass

3.1.8. The train was less than three kilometres (km) from Bridge 50 and was travelling at 58 km per hour when the train controller completed the authorisation process. The train controller did not ask the signals technician if he had seen the train, nor did he radio the train driver to ask of his location. KiwiRail's Rule 915 required the train controller to take both of these actions.

3.1.9. Although not required under KiwiRail's Rule 915, field staff in the area were familiar with the normal train schedule and frequently offered the train controller information on whether trains had passed their locations when making requests for track occupations. The train controller said that he had become accustomed to this practice and that he had come to depend on these prompts. However, in this case the signals technician was new to the area and did not offer any additional information.

3.1.10. The train driver overheard the authorisation being given on the train control radio and realised that a conflict with his train had been created. He reduced power on his locomotives and gradually brought the train to a stop a short distance from and within sight of Bridge 50. The train stopped at 1532.

3.1.11. The train driver radioed the train controller and informed him of the conflict. The train controller realised his error and radioed an instruction to the signals technicians to clear the track. The signals technician on the lead vehicle reversed his vehicle off the bridge. The second vehicle had not at that time been driven on to the track. The train continued its journey after a short delay.

3.1.12. The train controller was relieved of his duties pending KiwiRail's internal investigation. The train controller underwent a post-incident drug and alcohol test in accordance with KiwiRail's procedures. The test result was negative for performance-impairing substances.

3.2. Personnel information

3.2.1. The train controller was almost 59 years old at the time of the incident. He had started his career with KiwiRail in 1970 and spent the next 35 years working in field operations at various North Island rail terminals. He had transferred into train control in late 2005 and been certified to his first desk in March 2006. Certifications to the other two South Island desks had been attained by March 2009.

3.2.2. KiwiRail reported that the train controller had been involved in eight operating incidents between October 2008 and December 2011. KiwiRail had dealt with four of the incidents on an educational basis and noted the details on his file. The other four incidents had been identified and closed out during casual safety observations.

3.2.3. On 15 February 2012 the train controller had been involved in a track warrant control irregularity. In its internal investigation of this incident, KiwiRail had identified that the train controller had issues with concentration and distraction.

3.2.4. On 1 April 2012 KiwiRail had introduced medical standards for its train controllers in line with standards already applicable to its train drivers and other staff involved in safety-critical field work. The medical standards applicable to train control included a screening scale to help identify sleep disorders. The medical professional undertaking the examination was also required to request information relating to any fatigue-related symptoms.

3.2.5. The train controller had undergone his medical in July 2012 and been assessed as being fit for duty.

3.2.6. Following a track occupation irregularity on 20 July 2012, KiwiRail had placed the train controller on a support programme designed to help individuals with personal problems that could affect their operational performance. The programme had applied a series of additional performance assessments while the train controller continued to perform his duties.

3.2.7. The train controller had been involved in another operating irregularity when he applied a speed restriction to the wrong section of track on 21 April 2013. Following that incident the train controller had been placed on KiwiRail's Employee Assistance Programme. The programme included the train controller attending three counselling sessions with a clinical psychologist. He had attended his third session on the same morning as this incident.

3.2.8. Table 1 shows the train controller's shift rotations in the seven-week period leading up to the incident. Note "day(s)" off refers to a 24-hour midnight-to-midnight period.

Table 1: Shift rotation table

Week ending	Nature of shift rotation	Comment
20 April 2013	0700 to 1500 for 3 days and 1500 to 2300 for 2 days (shifts were non-consecutive)	2 days off
27 April 2013	1500 to 2300 for 1 day and 0700 to 1500 for 4 days (shifts were non-consecutive)	2 days off
4 May 2013	2300 to 0700 for 5 consecutive nights	1 day off
11 May 2013	0700 to 1500 for 5 consecutive days	2 days off
18 May 2013	1500 to 2300 for 5 evenings	2 days off
25 May 2013	2300 to 0700 for 5 nights	1 day off
2 June 2013	0700 to 1500 for 4 consecutive days	3 days off

3.2.9. Table 2 shows the train controller's work and non-work activities in the week prior to the incident. Had the incident not occurred, the train controller's roster would have had him completing a further two evening shifts.

Table 2: Hours worked during days leading to incident

June 2013	am	pm	Recreation activities
Mon 3	Roster day off – normal night's sleep		
Tue 4	Slept until 0700	Slept 3 hours, worked 2300-2400	Could not recall
Wed 5	Worked 0000 to 0700, slept 3 hours	Slept 3 hours, worked 2300-2400	Could not recall
Thu 6	Worked 0000 to 0700, slept 3 hours	Slept 4 hours, worked 2300-2400	Could not recall
Fri 7	Worked 0000 to 0700, slept 3 hours	Slept 3 hours, worked 2300-2400	Could not recall
Sat 8	Worked 0000 to 0700, slept 3 hours	Slept from 2300	Went for a 5 km run and followed grandchildren's sporting activities during the afternoon
Sun 9	Slept until 0800	Worked 1500 to 2300	Went for an 18 km run during morning
Mon 10	Slept until 0800	Started work at 1450*	Undertook household chores

*incident occurred at 1529.

4. Analysis

4.1. Introduction

4.1.1. Train control procedures should help to prevent mistakes by train controllers resulting in accidents and incidents. The following analysis discusses what went wrong for the train controller when he set up the conflict between the train and the work vehicles.

4.1.2. The analysis also considers the circumstances that contributed to the train controller's error. Two safety issues are discussed.

1. The train controller's shift pattern and how this likely contributed to his performance being affected by fatigue at the time of the incident.
2. Other human factors (known to KiwiRail) that probably contributed to the train controller being fatigued at the time of the incident, and specifically how these were being managed by KiwiRail.

4.2. What happened

4.2.1. The train controller was fully aware of the testing work underway on the Otira Tunnel door systems. It had been included in the daily information bulletin and the train controller had been briefed on the activity by the outgoing train controller during the handover at the start of his shift.

4.2.2. The train controller was aware of the presence and movement of the train right up to the time that he authorised the signals technician to occupy the same section of track near the western portal of the Otira Tunnel.

4.2.3. The train controller had set the departure signal to green to allow the train to depart the Otira station and then he had seen the train leave the Otira station on the signalling mimic screen at his workstation. He had updated its progress on the train control diagram. He was supposed to have endorsed the train control diagram with the actual time in minutes, but omitted to do so. Train controllers are required to record departure times in minutes as a permanent visual reference. This allows them to go back and view a train's last known time and location when considering requests for later track occupations.

4.2.4. It was unlikely that omitting to record the departure time of the train from Otira contributed to this incident, because it was only one minute later that the train controller authorised the signals technician to occupy the section of track in front of the train. Nevertheless, it was the first of a series of omissions by the train controller.

4.2.5. The audio recording of the train control workstation revealed that the train controller was not under a heavy workload at the time. It also revealed that there were no other radio calls from other parties and no other sources of distraction during the one-minute period between his last acknowledgement of the train's location and authorising the track occupation ahead of the train.

4.2.6. The next omission by the train controller was not verifying the exact location of the train before authorising the track occupation within the same section of track, as he was required to do by KiwiRail's rules. Instead he acted on an assumption that the train had already entered the Otira Tunnel and was clear of the western portal, based purely on the fact that the signals technician had requested the track occupation.

4.2.7. The signals technician followed the requirements of KiwiRail's Rule 915 when he requested the track occupation from the train controller. However, he was new to the area, and the train controller had become accustomed to previous technicians offering additional information about the locations of trains in the area.

4.2.8. The train controller could easily have verified the exact location of the train by any one or more of the following means:

- contacting the train driver and asking where his train was
- asking the signals technician if the train had passed over the bridge and entered the tunnel
- checking on his mimic screen to see whether the tunnel door indicator was showing open or closed.

4.2.9. The train was less than 3 km from Bridge 50 when the signals technician drove the first of two vehicles on to the track with the intention of crossing the bridge. It is fortuitous that the train driver overheard the track occupation being authorised and he followed the principles of good crew resource management to avert an accident.

4.2.10. The Commission has previously identified and commented on the safety issue of train controllers acting on assumptions. It made a finding in its Paerata report[1] that KiwiRail must take all available steps to ensure that train controllers did not act on assumptions and that train controllers must authorise track occupations on verified information only.

4.2.11. KiwiRail addressed this safety issue by introducing new track occupation procedures seven weeks after this incident (refer to the "Safety actions" section of this report). Train controllers are now prohibited from authorising track occupations while trains are occupying sections between stations in which the track occupations have been requested. The new procedures applied from 1 August 2013.

Findings

1. The train controller inadvertently created the potential for a head-on collision when he authorised the work vehicles to cross the rail bridge in the path of the approaching train. He did so without first checking the location of the train as he was required to by KiwiRail's rules.

2. A local practice had evolved over time whereby maintenance staff would normally not request time on track before any trains known to them in their location had passed. Acting on that local procedure, the train controller made an assumption that the train had already passed the signals technician's location. This assumption by the train controller did not comply with the KiwiRail rules and created a significant risk to the safety of the track maintenance and train staff.

4.3. Train control roster and fatigue

Safety issue – The standard roster that the train controller was working in the weeks leading up to the incident did not offer the train controller sufficient opportunity to recover from any sleep debt incurred after a shift cycle.

4.3.1. The train controller had been working in the role for more than six years. He said that he hadn't been sleeping well in the 18 months leading up to the incident and was feeling more pressured and stressed in relation to work shifts that he had previously completed without difficulty. He added that his "sleep quality had never been that good" despite his "trying hard to sleep" and that he had only been able to achieve normal sleep during his complete (24-hour) days off duty. He also added that his wife had noticed that he wasn't sleeping or resting and that he was tired.

4.3.2. The train controller said that in the eight weeks leading up to the incident he probably achieved a good night's sleep on only 14 of the 56 days. A review of his roster showed that there had been only five off-duty periods when he had two complete days off duty that gave him the opportunity to achieve two consecutive full nights of sleep.

[1] Commission report 11-106, hi-rail vehicle nearly struck by passenger train, Crown Road level crossing, Paerata, 28 November 2011.

4.3.3. Given the train controller's comments, and his performance and circumstances leading up to the incident, the Commission reviewed his medical history and engaged an expert in sleep research to review the train controller's shift pattern. Appendix 1 gives a description of the terminology used by the sleep expert.

4.3.4. The clinical psychologist said that on current formal testing there were some indications of possible subtle compromise in the train controller's initial processing of verbally presented information.

4.3.5. The clinical psychologist concluded that cumulative sleep deprivation over a long period of time was a likely cause of the train controller's having brief moments of reduced alertness. The psychologist noted that the train controller had had less than 48 hours' time off duty when he changed from his night shift week at 0700 on 8 June 2013 and resumed working at 1500 on 9 June 2013. The train controller's circadian rhythm would have been significantly disrupted by this.

4.4. Opinion of the sleep expert

4.4.1. Referring to the train controller's shift roster, the sleep expert said that given the timing of the incident, the likely length of prior wakefulness experienced by the train controller would have been 7½ hours. This was unlikely to have resulted in short-term fatigue-related performance impairments. The 40-minute period on duty prior to the incident and the moderate workload during this time would not have contributed to any time-on-task/workload-related performance decrements.

4.4.2. However, opportunities for recovery from any potential cumulative sleep debt did not occur frequently in the shift pattern in the eight weeks leading up to the incident. There was also the potential for a cumulative sleep debt to accrue in this roster, and not only when night shifts were worked. The relatively early start of the day shift at 0650 would, for most people, truncate night-time sleep.

4.4.3. It is difficult for an individual to go to bed early in an effort to extend their sleep when working early starting shifts due to the circadian drive for wakefulness in the evening. Evening shifts, which end at 2300, may also shorten sleep by delaying bedtime, although this very much depends on whether an individual is able to sleep for longer the following morning.

4.4.4. In the month prior to the incident (from 7 May onwards) the potential for a cumulative sleep debt to develop was high. This period began with 10 consecutive days of work and, although this period did not include night shifts, the long run of early starts and late finishes of the day and evening shifts respectively could have restricted sleep. After three days off the train controller worked five consecutive night shifts, and the requirement to sleep during the day was highly likely to result in the train controller obtaining less sleep and poorer-quality sleep than usual.

4.4.5. Subsequent to these night shifts the train controller was rostered for two days off (25 and 26 May). However, the preceding night shift finished on the morning of the first day off and the first day shift after the second night off required a relatively early start, possibly truncating this sleep episode. This limited period of time off is unlikely to have provided him with sufficient time to recover from the preceding night shifts.

4.4.6. This was followed by four day shifts (starting relatively early) then four days off. The early-starting day shifts could have added to any existing sleep debt, and when a sleep debt is allowed to occur and accrue, three to five days of recovery have been shown to be insufficient to return performance back to baseline (refer to Appendix 1 for more detail).

4.4.7. The four days off were followed by another series of consecutive night shifts (4 to 7 June) and again the daytime sleep was likely to have been shorter and of poorer quality than usual. The train controller stated that he usually obtained seven to eight hours of sleep at night and he was able to obtain between six and seven hours of sleep during the day from 5 to 7 June. This sleep was obtained in two blocks of approximately three hours.

4.4.8. There is presently little known about the restorative value of split sleep when sleep occurs during the biological day, therefore it cannot be determined whether splitting sleep into two relatively equal blocks would be better or worse than a single block of daytime sleep (or some other split-sleep arrangement). However, based on the amount of sleep obtained, the train controller would have accumulated a sleep debt of between 1½ and 4½ hours across the four consecutive night shifts (i.e. he obtained 1½ to 4½ hours less sleep than normally required across these four days). This sleep was also likely to have been of poorer quality and contain a greater number of awakenings than usual night-time sleep, and thus be less restorative.

4.4.9. The 32-hour break prior to the evening shifts commencing would not have provided him with sufficient opportunity to recover from any accumulated sleep debt accrued up until that point in time. The train controller slept for 12 hours during this time (one block of three hours during the day and a nine-hour period of sleep at night).

4.4.10. Previous research has shown that a 10-hour period of sleep following five nights of restricted sleep does not allow reaction time performance and subjective estimates of sleepiness and fatigue to recover. In the present situation, the night-time sleep opportunity was also likely to have been less than ideal due to the disruption of the circadian biological clock in conjunction with the previous night shifts.

4.4.11. The train controller then obtained another eight-hour period of night-time sleep prior to commencing his second evening shift, which commenced slightly later than the train controller's usual bedtime due to the finish time of the evening shift. If a significant sleep debt had accrued, these two night-time sleep periods (on 8 and 9 June) would have been unlikely to provide him with sufficient opportunity to recover fully.

4.4.12. The incident occurred at 1530, a point in the cycle of the circadian biological clock where sleepiness increases (also known as the afternoon nap window). This increased sleepiness could well have added to any existing fatigue caused by a cumulative sleep debt. The incident involved a failure of attentional processes by the train controller. This type of performance error is consistent with the behaviour expected of a fatigued individual.

4.4.13. The sleep expert concluded that it was "highly likely that the performance of the train controller was impaired by fatigue" and that "the fatigue was likely to have resulted from a cumulative sleep debt due to insufficient opportunities to recover from previous periods of work and was possibly exacerbated by a circadian-related increase in sleepiness (the afternoon nap window). The effectiveness of prior recovery periods during the eight weeks leading up to the incident may have been reduced by sleep difficulties experienced by the individual".

4.4.14. The sleep expert acknowledged that fatigue is "inevitable in any occupation where individuals are required to work when they would normally be asleep. Therefore a shift work environment will always be a matter of minimising rather than eliminating fatigue". She also said that "changing a roster system is only one way in which fatigue can be better managed in a shift environment. Because of individual differences and preferences there will never be a perfect roster in an environment where 24-hour operations are required. However, in saying this, consideration should be given to incorporating the following recommendations into the current roster system:

- A rostered day off should not commence the same day a night shift ends
- Limits are placed on the number of consecutive shifts that are able to be worked
- Adequate opportunities are provided to recover from any sleep debt prior to the next shift pattern commencing. At a minimum, two full nights of unrestricted sleep should be provided, although greater periods of recovery may be required depending on the number of consecutive shifts worked and the timing of those shifts".

4.4.15. KiwiRail should consider these recommendations when addressing the Commission's recommendations on this safety issue (refer to the section herein on the other relevant inquiries).

4.5. Opinion of the clinical psychologist

4.5.1. As noted earlier, the train controller had been referred to the KiwiRail employee assistance programme. As part of that programme the train controller attended three sessions with a clinical psychologist, who then produced a report to KiwiRail. The Commission obtained a copy of that report.

4.5.2. The clinical psychologist noted that the train controller had a reported history of some changes in memory in particular, which also appeared to correlate with changes in sleep, whereby he had become much less able to cope and adjust to changes in sleep (circadian rhythm) cycles in response to shift work. The report commented further on other issues that were preventing him sleeping and relaxing.

4.5.3. The clinical psychologist's report then referenced a number of papers citing the effects of shift work and fatigue on shift workers. In concluding on the effects of shift work, the clinical psychologist said:

> The above studies indicate that chronic sleep disturbance as a consequence of shift work can impact negatively on (for example) attention, memory, and affective states (i.e. mood and anxiety levels). There can be an accumulative effect on cognition when shift work is done over long periods of time. For some individuals this may not necessarily affect their work performance greatly. However, this depends on the nature of work. For the [train controller], his work requires frequently high level, consistent and sustained alertness and any lapse, even briefly, can have a significant impact. This makes his job much more stressful and pressured by virtue of any change in physiological state potentially reducing attention to the required level. [The train controller's] description of having brief occasional lapses in awareness but with still [being] able to work in an automatic manner (including asking questions and going through checks) suggests brief moments in reduced alertness are occurring. It is notable that the serious incident described occurred after sleep debt from night shift and then returning to a different shift within less than 48 hours. Thus circadian rhythms would have been significantly disrupted.

4.5.4. The clinical psychologist recommended that it would not be prudent for him to return to the role of train controller.

4.6. Summary

4.6.1. The sleep expert discussed several aspects of the train controller's roster that would have placed him at risk of accumulating a sleep debt. She concluded that it was highly likely that the train controller's performance was affected by fatigue, and that his roster did not provide him with sufficient opportunity to recover from any sleep debt that accumulated between shift cycles. She concluded that the train controller's sleep recovery periods might have been affected by sleep difficulties he was experiencing.

4.6.2. The clinical psychologist recognised that some of the problems the train controller was experiencing were related to his shift work and the lack of suitable opportunities to recover from certain shift cycles.

4.6.3. The potentially stressful nature of train control work, where the consequences of making an error can be serious, had begun to play on the mind of the train controller, and consequently had begun to affect his ability to gain sufficient, good-quality, restorative sleep.

4.6.4. It is likely that the train controller had been caught in a snowballing situation whereby his roster was not providing him with sufficient opportunity to recover from a sleep debt that was induced by the roster itself, which was then exacerbated by the train controller's anxiety over not sleeping well. Meanwhile, his fatigue-impaired performance was contributing to several incidents, resulting in his becoming more anxious.

4.7. KiwiRail management of underperforming train controllers

Safety issue – The train controller had been involved in three operating irregularities during the previous 16 months and KiwiRail had identified his having concentration and focus issues. Despite this KiwiRail had allowed him to continue in the train controller role.

4.7.1. The train controller had been identified by KiwiRail management as having concentration and focus issues in relation to tasks required for the safe execution of track occupation authorities as far back as February 2012. This was 16 months before the incident at the Otira Tunnel and after that time the train controller went on to have two further incidents. One of the two incidents was described by KiwiRail as creating a significant risk of a collision between a train and a hi-rail vehicle that had been authorised to occupy the track.

4.7.2. Management was monitoring the train controller's performance using standard assessment processes consisting of two types of safety observation. All train controllers undergo safety observations at least once in every eight months. As a result of this train controller's performance issues, KiwiRail increased the frequency to one four-hour observation about once every month.

4.7.3. KiwiRail defined the purpose of its safety assessment programme as providing the opportunity for management to evaluate a person's application and knowledge of the various rules, regulations and instructions applicable to the rail person's duties. The procedures were not specific about how management was to use this methodology in monitoring an individual identified with, for example, concentration and focus issues.

4.7.4. Train control is a mentally demanding and stressful role. Train controllers are required to make numerous quick decisions during their shifts and to get these decisions right all the time. Train controllers must be in peak mental form throughout their shifts to achieve this. A lapse of concentration could result in an accident, with consequent loss of life and/or significant damage to property and/or the environment.

4.7.5. Given the safety-critical nature of the train controller's role, and having already identified the problems the train controller was having with maintaining focus and attention while working the train control desk, a more prudent solution would have been to remove him from the role pending an investigation of his circumstances. The Commission has recommended that the Chief Executive of the NZ Transport Agency address this safety issue.

Findings

3. The KiwiRail train control roster did not allow sufficient opportunity for the train controller to recover from any sleep debt he may have incurred during any cycle of shifts.

4. The train controller's cognitive performance was highly likely impaired by fatigue at the time he authorised the vehicles to cross the bridge in the path of the oncoming train.

5. The train controller was performing a safety-critical role even after KiwiRail had identified performance issues similar to those that highly likely contributed to his authorising the work vehicles to occupy the section of track ahead of the train.

4.8. Other relevant inquiries

4.8.1. This is the fifth inquiry that the Commission has undertaken into the management and operations of KiwiRail's national train control centre in the past four years. The four previous inquiries were:

- in July 2010 the Commission published its report (08-110) into a potential low-speed, head-on collision at Amokura involving two freight trains (the Amokura inquiry)
- in September 2013 the Commission published its report (11-102) into a near-collision incident between Craigieburn and Staircase involving a coal train with two people on board and an alicart driven by a track engineer (the Staircase inquiry).
- in November 2013 the Commission published its report (11-106) into a near-collision incident at the Crown Road level crossing near Paerata involving a passenger train and five track maintenance workers about to on-track some heavy machinery (the Paerata inquiry)
- in January 2014 the Commission published its report (11-105) into a near collision when a freight train was routed into a section of track that had been closed for major upgrade work at Wiri Junction in South Auckland (the Wiri Junction inquiry).

4.8.2. Two substantive recommendations arose out of the four inquiries. The first recommendation (017/10 dated 21 July 2010 from the Amokura report) was issued to the Chief Executive of the NZ Transport Agency. It read as follows:

> *Standards for maximum working hours and minimum rest periods on the train control roster could result in a train controller being fatigued at the start of a shift even in the absence of any other fatigue-inducing factors. The train control roster policy including, but not limited to, standards for maximum working hours and minimum rest periods should be reviewed to ensure it is designed to mitigate fatigue and promote wellness.*

4.8.3. The second recommendation (014/13 dated 26 September 2013 from the Staircase report) was issued to the Chief Executive of KiwiRail. It read as follows:

> *Evidence reviewed by the Commission showed that at the time of the incident:*
>
> - *train control's workplace culture seemed to value those who operated independently and with minimal supervision*
> - *minimal training and education about detecting and managing stress and fatigue had been provided to train controllers, notwithstanding the safety-critical function that they were performing*
> - *poor systems existed within train control to detect and manage stress and fatigue in the workplace*
> - *the standard protocol within train control was to not provide train controllers with any certainty of reasonable breaks during their shifts.*
>
> *KiwiRail has implemented safety actions to ensure that train controllers receive alertness management training and medical assessments. However, the Commission is not convinced that these safety actions fully address the safety issues that it has identified regarding workplace culture, training and education.*
>
> *The Commission recommends that the Chief Executive of KiwiRail ensure that train control management has appropriate arrangements in place to:*
>
> - *detect and manage stress and fatigue, including appropriate training and education*
> - *remind train controllers about the importance of eating properly and regularly during their shifts*
> - *provide train controllers with certainty of reasonable breaks during their shifts.*

4.8.4. The following is a summary of actions taken to date working towards closing the two recommendations.

4.8.5. On 14 November 2013 KiwiRail issued a consultation document titled Changes to the Delivery of Access and Control Services. The document referenced two published Commission reports from the Amokura inquiry and the Staircase inquiry. The document said that KiwiRail needed to support high train controller performance with better supervision, training and audits to improve on the current rates of human error in the centre.

4.8.6. The NZ Transport Agency said that it had convened separate meetings with KiwiRail during May 2013 and January 2014 to monitor train control operational issues raised in the Commission reports and related recommendations.

4.8.7. In a document titled The Transport Agency's Action Plan to Improve Rail Safety Performance, dated 13 February 2014, the Transport Agency said that the management practices of train controllers was an area receiving an increased focus because of the higher risk status in this sector of the industry. The NZ Transport Agency noted that a recurring theme of the Commission's recommendations was the management of train controller rostering and fatigue. The specific actions being monitored by the Transport Agency included:

- management of KiwiRail's current restructuring plans of train control
- interim measures to combat train controller fatigue and distraction
- train controller rostering and leave management.

4.8.8. On 20 February 2014 the NZ Transport Agency said that it had multiple benchmarking discussions with an Australian metro train control operation, Airways New Zealand for air traffic control operations and New Zealand police/fire/ambulance emergency call centre operations.

4.8.9. On 11 June 2014 KiwiRail and the NZ Transport Agency informed the Commission that the train control management restructure signalled to occur in KiwiRail's consultation document of November 2013 had been completed. Train controller establishment and rostering had changed as a result of the restructure. The NZ Transport Agency added that it had requested a risk assessment to show how the changes from all the open recommendations had affected the level of risk in train control.

5. Findings

5.1. The train controller inadvertently created the potential for a head-on collision when he authorised the work vehicles to cross the rail bridge in the path of the approaching train. He did so without first checking the location of the train as he was required to by KiwiRail's rules.

5.2. A local practice had evolved over time whereby maintenance staff would normally not request time on track before any trains known to them in their location had passed. Acting on that local procedure, the train controller made an assumption that the train had already passed the signals technician's location. This assumption by the train controller did not comply with the KiwiRail rules and created a significant risk to the safety of the track maintenance and train staff.

5.3. The KiwiRail train control roster did not allow sufficient opportunity for the train controller to recover from any sleep debt he may have incurred during any cycle of shifts.

5.4. The train controller's cognitive performance was highly likely impaired by fatigue at the time he authorised the vehicles to cross the bridge in the path of the oncoming train.

5.5. The train controller was performing a safety-critical role even after KiwiRail had identified performance issues similar to those that highly likely contributed to his authorising the work vehicles to occupy the section of track ahead of the train

6. Safety actions

6.1. General

6.1.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

6.2. Safety actions addressing safety issues identified during this inquiry

6.2.1. On 18 July 2013 KiwiRail advised that its Network Operating Procedures, Train Control, Section 10.1, Instructions 14.1.2 and 14.1.3 would be amended by an information bulletin effective from 1 August 2013. These amendments and covering letter are shown in full in Appendix 2.

6.2.2. On 29 October 2014 KiwiRail advised the following safety actions had been taken to address issues it had identified in this inquiry:

> KiwiRail recognized that the potential of fatigue was not detected during the Employee Assistance Programme (EAP) and medical assessment process. Accordingly, we have engaged closely with the EAP Service Provider and the Medical Provider to strengthen the referral process. This process has implemented a stronger “return to work” clearance process that involves the Train Controller remaining off safety critical work until reviews are undertaken and clearances received. We have attached [provided the Commission] the Network Control document titled "Employee Wellbeing Support Framework" which outlines this process.

6.3. Safety actions addressing safety issues identified during previous inquiries conducted by the Commission

6.3.1. On 29 October 2014 KiwiRail advised the following safety actions had been taken to address issues it had identified during previous Commission inquiries listed in paragraph 4.8.1:

> This controlled document provides Network Control Managers and Supervisors with the appropriate tools and techniques required for supporting the well-being, health and safety of their team members including recognising and managing stress and fatigue.
>
> The document also provides Network Control staff, as part of their self-care and responsibility obligations, with the knowledge and techniques to manage health and well-being hazards they experience as part of their role. Network Control staff have therefore been provided with access to timely and appropriate levels of support (including EAP support and Registered Medical Officers (RMO) services) should it be required.
>
> National Train Control Centre staff and managers have attended well-being and fatigue workshops run by a Professor from the Public Health Department at Auckland University of Technology (AUT). As a standard practice, any new Train Control staff will be provided with the opportunity to attend future workshops. The Train Controllers have also been provided with a Tools and Techniques booklet for managing their well-being.
>
> A Registered Nutritionist has reviewed the snack foods provided to Train Controllers during their shifts and developed a new food plan (copy attached to this letter). This plan is to ensure that Train Controllers are provided with high nutritional value products suitable for sustaining them in their unique and demanding roles, which at certain key times requires a very high level of mental alertness. The new high nutritional value snacks are scheduled to be introduced from next month.

7. Recommendations

7.1. General

7.1.1. The Commission may issue, or give notice of; recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, one recommendation has been made to the Chief Executive of the NZ Transport Agency.

7.1.2. In the interest of transport safety it is important that this recommendation is implemented without delay to help prevent similar incidents or accidents occurring in the future.

7.2. Recommendation made during this inquiry

7.2.1. The train controller had been identified by KiwiRail management as having concentration and focus issues in relation to tasks required for the safe execution of track occupation authorities following a track occupation irregularity during February 2012. This was 16 months before the track occupation irregularity covered in this report, and during that period the train controller went on to have two further operating irregularities while he remained in the role.

*The Commission recommends to the **Chief Executive of the NZ Transport Agency** that he address with KiwiRail the safety issue whereby KiwiRail's standard policy and procedures allowed an "at-risk" train controller to continue working at train control workstations while undergoing a formal investigation and remedial process after KiwiRail had identified issues that would have affected his ability to perform his safety-critical role effectively (023/14).*

7.2.2. On 27 November 2014 the NZ Transport Agency's National Manager Rail Safety replied:

> Recommendation 023/14 that the Commission has directed to the Chief Executive of the NZ Transport Agency is accepted. Discussions on this recommendation will be initiated on the publication of the final report. These discussions will include a projected timeframe for implementation. This will be advised to the Commission in due course.
>
> The NZ Transport Agency has commenced the process for a Special Safety Assessment of KiwiRail's National Train Control Centre (NTCC) to be conducted, starting on Tuesday 20 January 2015. This will enable the Agency to have a greater level of insight into the NTCC operation to ensure that the licensed operator is operating within the requirements of its safety case.

8. Key lessons

8.1. It is important that train controllers do not make assumptions about the locations of trains when authorising track occupations, and do not use local or ad hoc practices to circumvent policies, procedures and rules designed to prevent accidents and incidents.

8.2. Train control is a safety-critical function. If there is any doubt about a train controller's performance, they should be stood down until all doubt is removed.

8.3. The 24-hour train control roster should be designed to minimise and manage the risk of train controllers' performance being impaired by fatigue.

9. References

KiwiRail Infrastructure and Engineering's Changes to the Delivery of Access and Control Services, consultation document dated November 2013 and provided to the Commission on 14 January 2014.

KiwiRail's rail operating rules and procedures, dated 10 June 2010.

Transport Accident Investigation Commission, Rail Occurrence Report 08-110, train control operating irregularity, leading to potential low-speed, head-on collision, Amokura, 23 September 2008.

Transport Accident Investigation Commission, Rail Occurrence Report 11-102, track occupation irregularity leading to near head-on collision, Staircase-Craigieburn, 13 April 2011.

Transport Accident Investigation Commission, Rail Occurrence Report 11-105, freight Train 228 wrong routed into closed section of track, Wiri Junction, South Auckland, 12 November 2011.

Transport Accident Investigation Commission, Rail Occurrence Report 11-106, Hi-rail vehicle nearly struck by a passenger train, Crown Road level crossing, Paerata, North Island Main Trunk, 28 November 2011.

Massey University of New Zealand, Report of Incident 13-106 Track Occupation Irregularity Leading to Near Collision on Bridge 50, Otira-Arthur's Pass, 10 June 2013, author Dr T L Signal, PhD, May 2014.

Neuropsychological assessment report of the train controller prepared for KiwiRail's train control manager by Kay Cunningham BA (hons), MA (applied) Comm, and Clin Psych (dist), MNZCCP on 2 August 2013.

NZ Transport Agency, The Transport Agency's Action Plan to Improve Rail Safety Performance, dated 13 February 2014.

NZ Transport Agency, Continuous Improvement in Rail Safety Regulation, dated December 2013.

Appendix 1: Extract from report by Dr T L Signal, PhD, Sleep/Wake Research Centre

Extract from the report on whether the roster and sleep patterns of the train controller involved in the incident could have affected his performance on the day by Dr T L Signal, PhD, Senior Fellow and Associate Director, Sleep/Wake Research Centre, Massey University of New Zealand, May 2014

Background information

Fatigue is a broad term, often used to describe a wide range of symptoms caused by factors such as continuous mental work, physical activity, sleep loss or the circadian biological clock. In this report the term fatigue will be used primarily to describe the consequences of inadequate sleep or functioning at an adverse circadian phase.

Sufficient good quality sleep is vital to sustaining normal levels of functioning. The amount of sleep required on a daily basis varies from one individual to the next, with the average being approximately 7-8 hours, but some individuals require as little as 6 hours of sleep and others as much as 10 hours.

When a short term or long term change in sleep results in less or poorer quality sleep than an individual's ideal daily sleep need, a sleep debt is said to occur and accrue.

Acute sleep loss

Acute sleep loss results from both total sleep deprivation and also a single night of restricted or disrupted sleep. For a shift worker, complete sleep deprivation for a 24-hour period may occur occasionally, such as in association with the first night shift but is probably less frequent than episodes of reduced sleep.

It has been shown that curtailing the usual amount of sleep for one night by as little as 2 hours produces measurable increases in sleepiness while decrements in performance are most apparent once sleep is restricted to 5 hours or less in a single night.

It is not only the amount of sleep obtained, but also the quality of sleep that is important. One night of disturbed sleep (sleep that is lighter and fragmented by awakenings) is also related to increased sleepiness and decreased performance and mood.

Cumulative sleep debt

When sleep is restricted or disturbed for more than one night, the effects accumulate and a sleep debt builds. There is strong and consistent evidence indicating decreased performance and mood with an increasing sleep debt.

Two seminal studies have shown that restricting sleep to between 3 hours and 7 hours per night for 1-2 weeks results in a near linear decline in performance, with the rate of decline in performance increasing with increasing sleep restriction. Subjective sleepiness also increases with increasing sleep restriction but to a lesser degree than the decline in performance. Thus, individuals underestimate the extent to which their performance is affected when sleep is chronically restricted. Furthermore, after periods of sleep restriction (e.g. 2 weeks of only 6 hours in bed), performance was shown to be equivalent to that seen under conditions of total sleep deprivation (e.g. sleep loss for 24 hours), indicating that chronic partial sleep restriction can induce deficits in the waking brain that are similar to total sleep deprivation.

More recent studies have also shown that chronic sleep restriction interacts with circadian phase resulting in the poorest performance during the biological night.

A further study investigated the effects on performance of splitting sleep into a night time sleep episode and a day time nap over 10 consecutive days. Like earlier studies, findings showed an almost linear relationship between the amount of sleep obtained in 24 hours and performance degradation. Importantly though, it did not appear to matter whether sleep was obtained in one block or two but it must be noted that the largest block of sleep (between 4.2-8.2 hours) was obtained during the biological night.

Recovery from a sleep debt

A single night of recovery sleep is not considered sufficient to compensate for fatigue that has built up over an extended period of time, even if that recovery sleep is extended to 10 hours in bed. In one of the studies of cumulative sleep debt mentioned above, it was noted that performance did not recover back to baseline even after 3-days of 8 hours per night in bed. The authors of this study suggest that chronic sleep restriction leads to long term and constant changes in functioning that help an individual adapt to the effects of continued sleep restriction. However, these changes come at a cost, so that when sleep duration is extended and recovery allowed, a return to baseline levels of alertness and performance does not occur immediately.

A recent study has shown that even 5 nights of 8 hours recovery sleep was not sufficient to return performance to that seen prior to a 7 nights of restricted sleep, but performance did recover more rapidly in individuals who had extended their sleep prior to the week of sleep restriction.

Expert working groups in trucking have recommended that at least two full nights of unrestricted sleep are required on a regular basis (preferably weekly) so that a significant sleep debt cannot accrue. Unrestricted night time sleep refers to an individual being able to go to bed and rise when they choose.

Extended wakefulness

It has been demonstrated that 8-hours of night time sleep provides about 16 hours of day time wakefulness, after which decrements in performance appear. It has also been shown that after 17 hours of sustained wakefulness across the biological night, performance will decrease to a level equivalent to that observed when an individual is at the legal limit for blood alcohol concentration. Several other studies also demonstrate that sleepiness increases with extended wakefulness.

Changes in cognitive performance with sleep loss

There is often debate as to how well the performance changes seen on laboratory tasks, such as those discussed above in the studies of acute sleep loss and cumulative sleep debt, relate to “real world”, or more cognitively complex, performance.

Cognitive skills are thought to be reliant on the functioning of the prefrontal region of the cerebral cortex and recent evidence has shown that this area of the brain is affected by as little as one night of sleep loss. Both simple and complex cognitive tasks show deficits following sleep restriction including sustained attention and reaction time, working memory and cognitive throughput. Harrison and Horne discuss evidence that suggests a raft of higher level cognitive skills are adversely affected by sleep loss. Those affected include: attending to complex information while filtering out distractions, following a situation and recognising the need to apply new strategies, lateral thinking and innovation, risk assessment, maintaining interest, controlling mood and behaviour, the ability to self-monitor performance, and the ability to communicate effectively.

Circadian biological clock

Humans have peaks and troughs in daily functioning across a range of physiological and behavioural variables, including temperature, hormone levels, the sleep-wake cycle, mood and performance. These daily variations are controlled by a group of cells located in the brain referred to as the circadian biological clock. The circadian clock effectively “programmes” us for wakefulness during the day and sleep at night.

Due to the circadian biological clock, sleepiness is maximal in the early hours of the morning (approximately 3-5am) with another, smaller peak in the middle of the afternoon (approximately 3-5pm). Although maximal sleepiness is in the early hours of the morning, performance and alertness can be affected throughout the 12am to 8am window.

The circadian system also helps maintain wakefulness during the day, making it difficult for individuals who are working at night and sleeping during the day to obtain sufficient good quality sleep. In fact, on average night workers get approximately 2-4 hours less sleep per 24 hours than day workers. Thus for a shift worker, consecutive night shifts are likely to result in the rapid accumulation of a sleep debt. Night shifts are not the only mechanism through which a sleep debt can accumulate. Early morning shifts that truncate night time sleep can also shorten sleep significantly and although individuals may attempt an earlier bed time in "preparation" for an early start, the circadian biological clock promotes wakefulness in the few hours before a person's habitual bedtime making it difficult to fall asleep earlier than usual.

Shift work

The circadian clock keeps in time with the 24-hour day-night cycle by environmental cues, particularly exposure to light. The pattern of work and rest, physical activity and social interaction are additional, weaker cues that help keep the clock in time with the day-night cycle.

When a shift worker changes to a new shift schedule, such as working at night and sleeping during the day, many of the cues that keep the circadian clock in time with the day-night cycle encourage the circadian pacemaker to shift to the new pattern of work and rest. As a consequence, the body's systems get out of step with the day-night cycle and importantly also each other. The same occurs after travel to a new time zone.

For a shift worker there is a further complication. The change in the pattern of work and rest creates conflicting cues for the circadian clock, which attempts to adapt to the new pattern of activity and sleep, but is constantly drawn back to its diurnal orientation by exposure to daylight. The result is incomplete adaptation to the new work pattern. Gander et al. demonstrated this in overnight cargo pilots flying domestic routes. The pilots crossed no more than one time zone in 24 hours and normally worked either three or five night shifts in a row. It would be expected that if the pilots completely adapted to their night schedules then their circadian rhythm of body temperature would shift by 12 hours. However, the study findings indicated that on average the rhythm of body temperature only changed by 2.8 hours.

In addition, frequent changes in the pattern of work and rest have the potential to result in the circadian clock being almost constantly out of step with the 24 hour light-dark cycle, resulting in the shift worker constantly experiencing jet-lag like symptoms.

Sleep disorders

There are a large number of sleep disorders, some of which are relatively common in the general population including sleep apnoea, insomnia, circadian rhythm disturbances and movement related sleep disorders. Physical and psychological health conditions, particularly those that result in pain, discomfort or anxiety, can also result in disturbed sleep. Sleep disorders are of relevance due to the disruption to sleep and the potential impact on waking functioning including impaired performance, increased accidents or incidents while driving, sleepiness, poor mood and poorer social adjustment.

Time on task fatigue

One further factor that deserves to be mentioned in this context is time-on-task fatigue. This refers to reduced performance as a consequence of continuously performing mental or physical tasks. Complex tasks and tasks involving vigilance are particularly susceptible to this type of decrement.

Time-on-task fatigue is exacerbated by both acute sleep loss and a cumulative sleep debt. Circadian phase is also thought to influence the extent to which time-on-task fatigue is experienced, with greater performance decrements for similar periods of time-on-task during the night hours.

Time-on-task fatigue can be minimised with the provision of adequate rest breaks within a shift and limiting the duration of a shift. The length of a work period before a rest break occurs, and the duration of the rest break, is somewhat dependent on the type of task being performed. Much of the early work in this area focussed on tasks where sustained attention was required (e.g. monitoring for an infrequent event). This work demonstrated that performance declined consistently over time and that breaks of as little as 5 minutes could improve performance.

Appendix 2: KiwiRail's New Track Occupation Section Clear Procedures and associated Safety Briefing

KiwiRail

18 July 2013

Train Controllers
National Train Control Centre
WELLINGTON

Dear Colleague,

New Track Occupancy Section Clear Procedure

The authorization and protection of track occupancy is the most safety critical task that you are required to perform. We rely on accurate procedural checks and clear communication.

As these processes rely on you doing a series of manual checks and decisions, they are prone to mistakes being made – Miscommunication, one check or task not done etc. We mitigate these by cross-checking.

A critical review of the track occupancy procedures has identified that train controllers failing to correctly identify the last train clear of an on-tracking location is an error that is not able to be challenged or cross checked by the person who could be harmed. Field staff are not able to have any real/accurate situational awareness about train position. This is a single point of failure.

Recent incidents have made us look at this again at how we mitigate this risk.

When we apply the (Railways Act) test to "*take all practicable steps on its part to ensure that none of the rail activities for which it is responsible causes, **or is likely to cause**, the death of, or serious injury to, individuals*", we must make change to reduce this hazard.

We have conducted two conference workshops with Area Managers and run a risk workshop with RMTU input to determine options for improvement. A recommendation was made to the executive management team who have decided to implement new procedures requiring on-tracking sections to be train-free before granting occupancy. This requirement will commence on 1 August 2013.

This change is the only appropriate choice (given the current technology) that passes the *all practicable steps* test. I'm confident future technology use will offer us more opportunity for safety change in coming years.

This new requirement will mean more waiting time by field staff. We are issuing tool box briefings to advise of this change with support from Regional and Area Managers and we want your feedback if field staff raise concerns about waiting. At a more strategic level, work is underway to implement weekly train free block-of-line type time periods for more intensive coordinated maintenance activity. Two such time periods are now operating on the Midland/SWL and ECMT and more will follow this financial year.

KiwiRail | **www.kiwirail.co.nz** | Level 4, Wellington Railway Station, Bunny Street, Wellington 6011
PO Box 593, Wellington 6140, New Zealand | Phone **0800 801 070** Fax +64-4-473 1589

Provided with this letter is a Safety Briefing titled "Section Clear for Occupancy". Please read this in conjunction with this letter as it defines the detail and interpretation of this safety change. Briefing sessions will also be conducted by Network Control Managers where you will be asked to sign an acknowledgement of briefing and new Bulletin instructions.

Please maintain the utmost diligence in your track occupancy tasks recognising that safety defences come from the consistent and correct application of these procedures by both train control and field users.

Yours sincerely

Manager Network Operations

KiwiRail

Safety Briefing

For all Train Control Personnel

SECTION CLEAR FOR OCCUPANCY

A significant hazard exists of Train Control & track users not correctly establishing that a train in a section has passed a proposed on-tracking location. We have had near collisions caused by confusion of train numbers, coloquial phrases, and/or assumption.

Following review by the KiwiRail Group Executive Manangement team, a change is being introduced to require that track occupancy under Rules 908, 909, 915 or 918 must NOT be granted for any on-tracking location that has a train still occupying the same section.

In practice, in most CTC and ASR territory, this means that blocking would be fully applied (and not in "pending" state) to the on-tracking section before granting occupancy.

In dark territory, to verify a train is clear of a section, Train Control MUST make/ receive a verbal call to/from the relevant train/s **directly with the LE** about their current location which must be beyond the next station. Information from field staff about the passing of trains **must not** be relied upon.

Train Control Operating Instructions Section 10.1 Instructions 14.1.2 and 14.1.3 are being modified by Bulletin to require **from 1 August 2013**:

Where track safety rules require train control to verify the position of a train to ensure that it is passed the on-tracking location, this must be performed by:

- Observing all track circuits are clear within the on-tracking location when within station limits of an interlocked station, or
- Observing **all** track circuits are clear between adjacent stations for any continuously detected block section, or
- Obtaining verbal advice and confirmation of a trains position from the Locomotive Engineer that it is clear of the **next station** (incl Metro Platforms & Intermediate Boards) when the on-tracking location is in dark territory or non-continuously detected section (DLAS, TWC, SLAS, ASR)

Continued on Page 2 ...

SECTION CLEAR FOR OCCUPANCY

To provide practical examples of the application of this rule:

Request	Rule requirement before allowing authorisation
On-track on Up Main at 633.5km NIMT Crown Rd Paerata	Last train must have verbally confirmed arrived clear inside station limits Papakura
On-track on Down Main at 606.6km NIMT Oram Rd Mercer - Amokura	Last train must have arrived clear through Amokura by panel observation with blocking fully applied
On-track on Up Main at 621.6 Harrisville Rd between Pukekohe and Mercer	Last train must have verbally confirmed arrived clear at/through Pukekohe
On-track on the Up Main at 2.6km Wairarapa Line Kaiwharahara	Last train must have verbally confirmed clear of Ngauranga Station
On-track at 48.7km Midland Line Pocock Rd station limits Springfield	Last train must have cleared station limits Springfield by panel observation with blocking fully applied
On-track at 60.0km Midland Line between Springfield and Staircase	Last train must have verbally confirmed clear of Springfield or Staircase
On-track at main inside station limits Staircase	Last train must have verbally confirmed clear of station limits Staircase
On-track at 37.0km ECMT between Morrinsville and Kereone	Last train must have cleared the section through Kereone or Morrinsville by panel observation with blocking fully applied
HRV on loop waiting to follow train into section	Last train has cleared the points giving entry to follow
On-track at 346.0km MNL between 2R and 4R Picton	Last train must have cleared track between 2R and 4L by panel observation with blocking fully applied
On-track using foul time at 90.0km MNPL between Waitotara and Patea	Last train must have verbally confirmed arrived clear at/through Patea or Brewer Road IB

Note:

- Pending blocking is permitted for sections beyond the on-tracking section to follow a train.
- This new instruction does not affect or limit the use of after the departure/arrival Track Warrants.

Summarised locations that trains must be clear of are:
CTC/ASR Single Line blocks – Next Station
DLAS/ASR Multi-Line – Next interlocked station or passenger platform
Station Limits – any fixed controlled signal clear of the on-tracking track
TWC for Foul Time only - Next Station or Intermediate Board

Manager Network Operations
18 July 2013

Recent railway occurrence reports published by the Transport Accident Investigation Commission (most recent at top of list)

RO-2012-102	Train control power failure, 26 April 2012
Interim Report RO-2014-103	Metropolitan passenger train, collision with stop block, Melling Station,Wellington, 27 May 2014
RO-2013-102	Passenger train travelled with doors open, Wingate - Taita, 28 March 2013
12-101	Load shift on Train 926D struck stationary, Train 845, Main South line, Rolleston, 6 April 2012
11-105	Freight Train 228 wrong-routed, into closed section of track Wiri Junction, South Auckland, 12 November 2011
RO-2013-108	Near collision between 2 metro passenger trains, Wellington, 9 September 2013
11-106	Hi-rail vehicle nearly struck by passenger train, Crown Road level crossing near Paerata, North Island Main Trunk, 28 November 2011
11-102	Track occupation irregularity, leading to near head-on collision, Staircase-Craigieburn, 13 April 2011
RO-2013-104	Urgent Recommendations: Derailment of metro passenger Train 8219, Wellington, 20 May 2013
11-103	Track workers nearly struck by passenger train, near Paekakariki, North Island Main Trunk, 25 August 2011
10-101	wrong route setting, high-speed transit through turnout, near miss and SPAD (signal passed at danger), Tamaki, 13 August 2010
11-104	Freight Train 261 collision with bus, Beach Road level crossing, Paekakariki, 31 October 2011
10-102	collision between 2 metro passenger trains, after one struck a landslide and derailed between Plimmerton and Pukerua Bay, North Island Main Trunk, 30 September 2010
07-102	(incorporating inquiry 07-111) freight train mainline derailments, various locations on the national network, from 6 March 2007 to 1 October 2009
11-101	Wrong line running irregularity, leading to a potential head-on collision, Papakura - Wiri, 14 January 2011

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