Report 07-108, express freight Train 720, track warrant overrun at Seddon, Main North Line, 12 May 2007

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express freight Train 720

track warrant overrun at Seddon

Main North Line

12 May 2007

Abstract

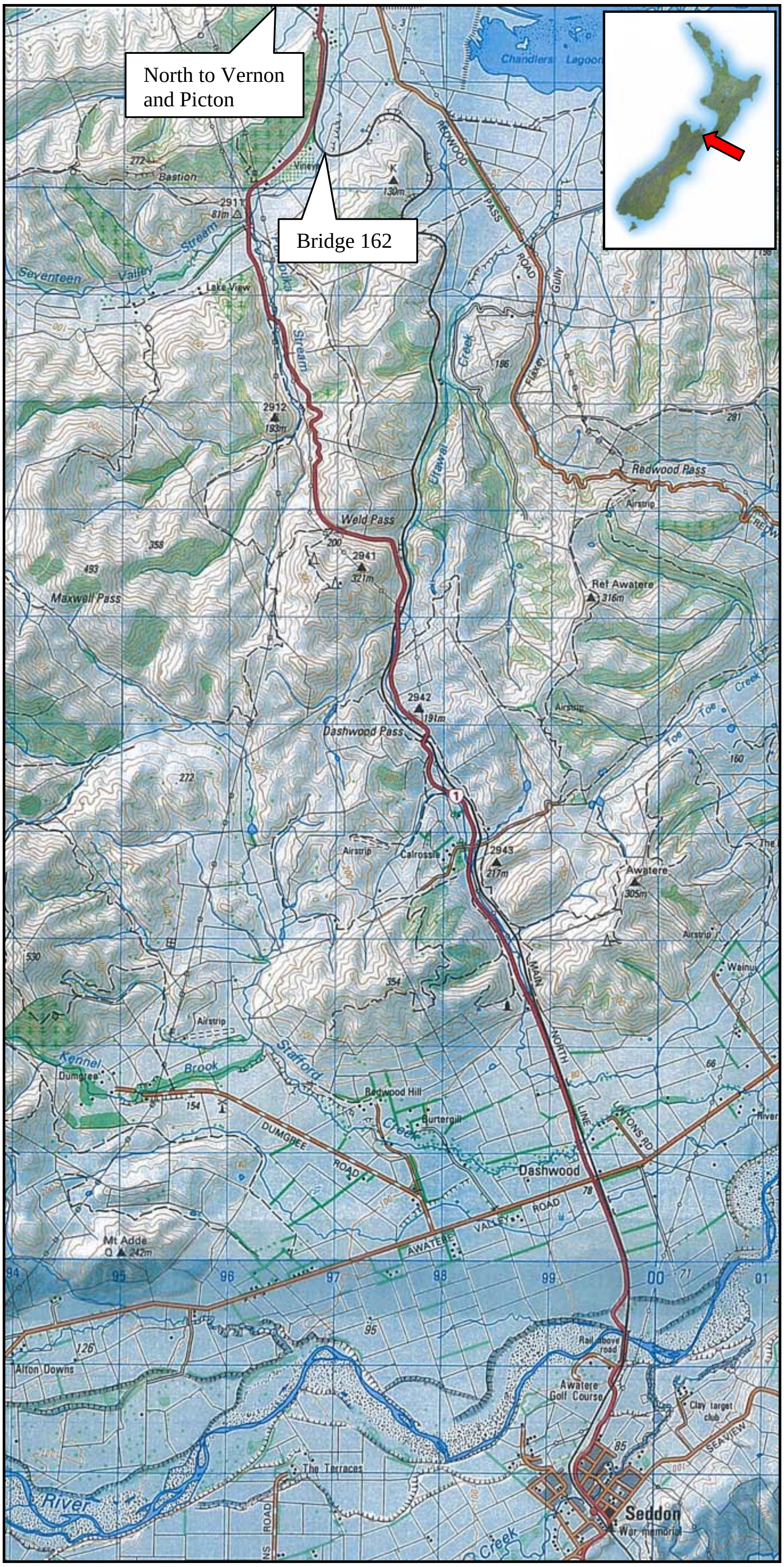
On Saturday 12 May 2007, at 0400, northbound express freight Train 720 travelled past Seddon towards Vernon on the Main North Line without the authority of a track warrant issued from train control.

The locomotive engineer did not stop on the main line at Seddon as required and obtain a new track warrant to travel beyond Seddon. Southbound Train 723 was sitting on the loop when Train 720 passed through Seddon. There were no other conflicting movements and as a result there was no damage or injury.

Safety issues identified were:-

- management of fatigue in train operations
- detecting sleep disorders
- locomotive engineer vigilance systems
- crew resource management
- monitoring of rail vehicles on non-track-circuited sections of the controlled network.

Four safety recommendations have been made to the Chief Executive of the New Zealand Transport Agency to address theses issues.



MNL from Seddon towards Vernon

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Abbreviations

CRM	crew resource management
GPS	global positioning system
km	kilometre(s)
km/h	kilometre(s) per hour
m	metre(s)
MNL	Main North Line
NTSB	National Transportation Safety Board
Toll Rail	Toll NZ Consolidated Limited
TWACS	track warrant assisted computer system
USA	United States of America
UTC	universal coordinated time
VHF	very high frequency

Data Summary

Train type and number:	express freight Train 720
Date and times:	Saturday 12 May 2006, between 0400[1] and 0428
Location:	Seddon, Main North Line
Persons on board Train 720:	one
Injuries:	nil
Damage:	nil
Operator:	Toll NZ Consolidated Limited
Investigator-in-charge:	Vernon Hoey

[1] Time in this report are New Zealand Standard Time (UTC + 12) and are quoted in the 24-hour mode.

1 Factual Information

1.1 Narrative

1.1.1 On Friday 11 May 2007 at 1855, a Toll NZ Consolidated Limited (Toll Rail)[2] team leader locomotive engineer[3] booked on for duty at Picton. He was rostered to drive southbound Train 737 from Picton and return on northbound Train 720, both trains being scheduled express freight services on the Main North Line (MNL). The locomotive engineer was scheduled off duty at 0445 on Saturday 12 May 2007.

1.1.2 The locomotive engineer drove Train 737 to Ferniehurst where, at about 0045 on Saturday 12 May 2007, he completed a crew change with Train 720 (see Figure 1). Train 720 consisted of DFT7077 hauling 1101 tonnes with a length of about 450 metres (m). The locomotive engineer was issued with a track warrant by train control for Train 720 to travel from Ferniehurst to Pines.

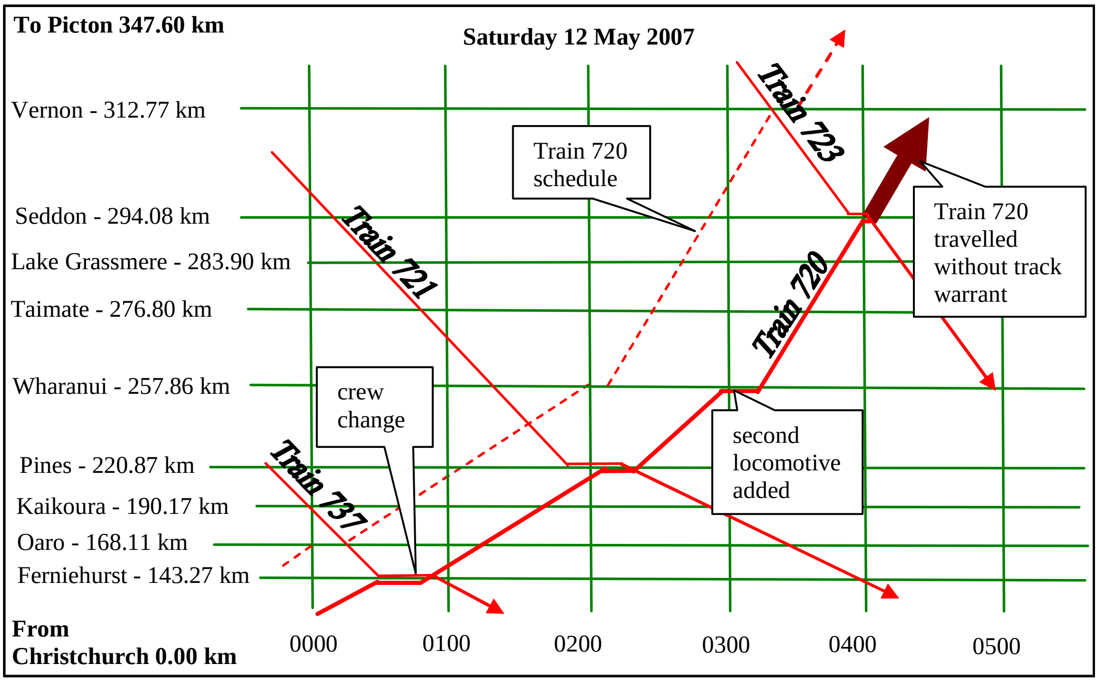

Figure 1
Details of train movements as recorded on the train control diagram (not to scale)

1.1.3 At 0221, after crossing Train 721 and because Train 720 was now about 60 minutes behind schedule, the train controller issued the locomotive engineer with a track warrant to travel from Pines to the main line at Seddon to cross Train 723, another southbound service. Train 720 was timetabled to cross Train 723 at Vernon (see Figure 1).

1.1.4 Train 720 was routed to the loop at Wharanui and a second locomotive was coupled to the train to provide additional motive power for the steep gradients on the remainder of the journey to Picton. A shunter from Picton assisted the locomotive engineer with this task. Train 720 departed Wharanui at 0313.

1.1.5 While Train 720 was passing through Lake Grassmere, the locomotive engineer heard his colleague on Train 723 make his mandatory channel one radio call on his approach to Seddon. The 2 locomotive engineers conferred by radio and agreed that Train 723 would berth first because it was the closest to Seddon.

[2] Toll Rail was the owner of the train-operating company at the time of the incident.
[3] Throughout the report the team leader locomotive engineer will be mostly titled as locomotive engineer.

1.1.6 The locomotive engineer of Train 720 could not recall if he made his mandatory call when he sighted the station warning board[4] approaching Seddon but recalled that he had waved to his colleague on Train 723 as the locomotives passed each other (see Figure 2).

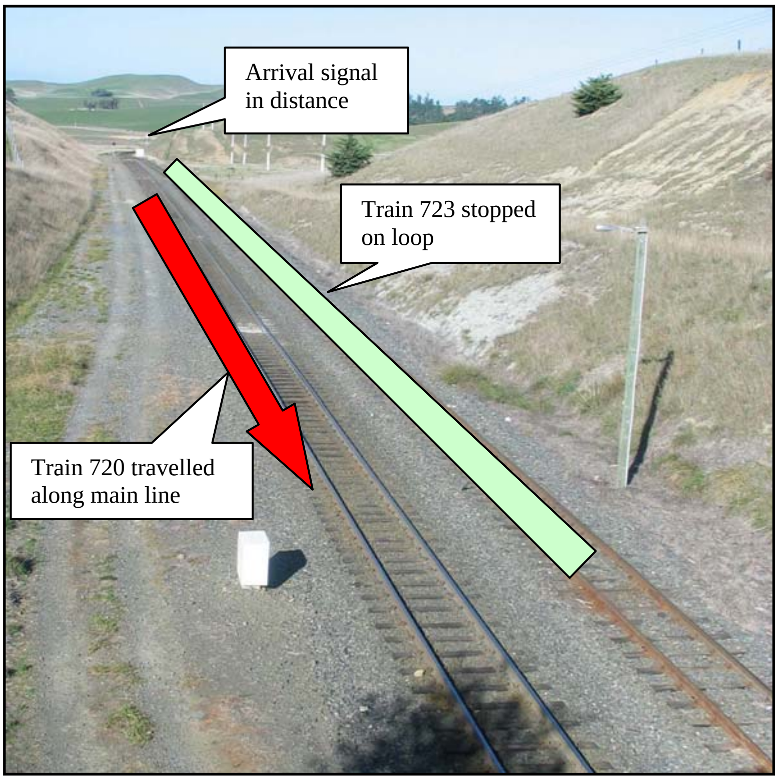

Figure 2
South end of Seddon

1.1.7 After the rear of Train 720 had passed by and the aspect of the trailing points indicator changed to a purple indication, and because he was already in possession of a track warrant, the locomotive engineer of Train 723 released the brakes and the train moved off. The locomotive engineer of Train 723 said that he thought Train 720 was not going to stop at Seddon and did not hear him radio train control as he had expected.

1.1.8 Meanwhile Train 720 did not stop on the main line at Seddon as required, to obtain a track warrant from train control to travel to Vernon.

1.1.9 The locomotive engineer of Train 720 said that he could not recall anything during the journey from Seddon towards Vernon. The first the locomotive engineer knew of an incident occurring was when he received a radio call from train control 28 minutes after leaving Seddon. By that time, Train 720 was approaching Bridge 162 at 309.65 kilometres (km), about 15 km from Seddon. The locomotive engineer stopped his train at 0430.

1.1.10 The train controller authorised Train 720 to continue the short distance to Vernon where the locomotive engineer was subsequently relieved from his driving duties.

[4] A visual warning to locomotive engineers, located between 800 m and 1300 m from a warrant station.

1.2 Personnel

Team leader locomotive engineer (Train 720)

1.2.1 The locomotive engineer of Train 720 was a certified Grade 1 locomotive engineer with 28 years of driving experience accumulated in Wellington and Picton. Following a period in a front-line management role in Picton, he had attained his current position of team leader locomotive engineer in 2000.

1.2.2 The team leader locomotive engineer's duties required him to assess locomotive engineer performance and also the training and assessment of remote control operators[5]. He said that he needed to set an example to these members who he was required to coach, counsel and assess, and as such he was required to respond to all levels of non-conforming practices brought to his attention and raise these matters with the member concerned. He was also expected to undertake train driving duties.

1.2.3 The locomotive engineer said that staff shortages during the 6 months prior to the incident meant that he had been called upon to perform train driving duties on the days that he was rostered to undertake team leader duties. At one stage there were 3 locomotive engineers not available for driving duties for different reasons. In addition to the team leader and train driving responsibilities, he could be called out to manage an operating incident such as a mainline derailment and was called upon to cover the local manager during his absences and occasionally undertake locomotive servicing duties.

1.2.4 The locomotive engineer said that because of the amount of train driving he was doing during that 6 month period, he had made approaches to management because he "felt that he did not have enough time" to complete his required team leader responsibilities.

1.2.5 The locomotive engineer said that he felt "pretty well rested" following a 2-week annual leave period at a South Island resort. His first day back at work on Monday 7 May coincided with the introduction of a new roster, but instead of resuming his team leader responsibilities, he was requested and agreed to drive a work train. He then undertook his rostered train driving shifts on Tuesday 8 and Wednesday 9 May.

1.2.6 To compensate for the lost team leader day on the Monday, he arranged for another locomotive engineer to undertake his rostered train driving shift on Thursday 10 May. He completed 2 safety observations and the associated administration activities that day and finished work at about 1600.

1.2.7 That night, he said, he had a normal night's sleep and rose at about 0730 on Friday 11 May. He occupied himself around home by mowing the lawns in the morning and "messed about" on the computer and tried to relax during the afternoon. He had a meal in the early evening before booking on for duty at his rostered time of 1855.

1.2.8 The journey south on Train 737 was uneventful. While travelling over a lengthy speed restriction near Lake Grassmere, the locomotive engineer took advantage of the slower speed to have "a cup of coffee and a couple of scones". He could not recall if he stopped anywhere on the southbound journey of 204 km to Ferniehurst. He spent only a few moments changing over to Train 720 before obtaining a track warrant which he placed on an illuminated clipboard provided for the purpose.

[5] The job title of the operator of remotely controlled shunt locomotives.

1.2.9 During the journey north, Train 720 was routed via the loop at Pines to cross Train 721, a movement that did not require the locomotive engineer to leave the cab. At Wharanui the locomotive engineer liaised with the roving shunter while the second locomotive was coupled to the train. He enjoyed the opportunity to get outside the cab during the shunting movements and also enjoyed talking to the shunter.

1.2.10 The locomotive engineer radioed the train controller to report his progress after Train 720 had left Wharanui. Detail of this call was recorded in the voice recording system installed in train control. The locomotive engineer could not recall if he made his mandatory channel one radio call when approaching Taimate sometime afterwards, but added that it was his normal practice to comply with the mandatory radio calling procedures. However, unlike radio calls between the locomotive engineer and train control, channel one calls were not recorded.

1.2.11 The locomotive engineer could also not recall making his mandatory radio call approaching Seddon, but saw the yellow aspect (normal speed indication, proceed with caution) on the arrival signal. At that point he switched his cab light on to make himself visible to the locomotive engineer of Train 723. The locomotive engineer said that after passing his colleague on Train 723, he also could not recall continuing through Seddon and even after "wracking my brains" he was not able to remember controlling the train for the next 28 minutes.

1.2.12 The locomotive engineer realised that "I was where I shouldn't be" when he answered the radio call from train control.

Locomotive engineer Train 723

1.2.13 The locomotive engineer of Train 723 was a certified grade 1 locomotive engineer with 47 years driving experience accumulated in Oamaru, Otira and Picton where he had been based for the previous 35 years. His certifications were current.

1.2.14 The locomotive engineer said that after he received a response to his channel one call from the locomotive engineer of Train 720, he entered the loop at Seddon stopping about 70 m from the trailing indicator. He recalled hearing the locomotive engineer of Train 720 saying that he would see him shortly. He then placed his radio to scan and did not hear if the locomotive engineer of Train 720 made his channel one call approaching Seddon.

1.2.15 The locomotive engineer saw the cab light illuminate when Train 720 approached and saw the locomotive engineer wave to him as he went past. He thought that the locomotives were under full power when they went past. He would have normally expected a locomotive engineer to have reduced power by that stage in preparation for stopping at Seddon.

1.2.16 After Train 720 had completely passed and the trailing indicator had changed to a proceed aspect, the locomotive engineer of Train 723 released the brakes and let the train roll away down the gradient. He did not hear the locomotive engineer of Train 720 make a radio base call and assumed that either he had stopped for a personal needs break or had telephoned train control on his cellphone for his ongoing track warrant.

1.3 Site and operating information

1.3.1 The track from Christchurch to Picton was single line over a distance of 347.60 km with a maximum operating speed of 80 kilometres her hour (km/h) for express freight services. The section of track between Seddon and Vernon was heavily graded as it climbed from the north and south to the Dashwood Pass (refer Figure 6). The many sharp-radius curves either side of the Dashwood Pass required speeds to be reduced to between 45 km/h and 55 km/h.

1.3.2 Train movements on the MNL were controlled from Ontrack's national train control centre in Wellington. Operating systems were installed as follows:

- centralised traffic control from Christchurch to Belfast
- track warrant control from Belfast to Vernon
- centralised traffic control from Vernon to Picton.

Centralised traffic control was an automated signalling system remotely monitored and operated from train control. Conversely, track warrant control was not an automated signalling system.

Track warrant control

1.3.3 The track warrant control operating system was introduced to the New Zealand rail network in 1988 as an alternative to other single-line operating/signalling systems installed on secondary and branch lines. Track warrant control was also installed on some main lines that traditionally carried a low volume of traffic in comparison with other main lines. Track warrant control was installed over 2254.74 km, representing about 56% of the national rail system.

1.3.4 Track warrant control was designed to achieve the fundamental principle of any railway operating system; to ensure only one train or rail vehicle had authority to occupy a section of track at any one time. Train control gave authority to occupy a section of track by issuing a track warrant. The train controller issued the track warrant to an addressee[6] who had charge of any train or other type of authorised rail vehicle before an occupation or fouling of the section of track could occur. The addressee was required to understand and comply with the limits and conditions of the track warrant which included the requirement to advise train control of journey progress after passing specified wayside locations.

1.3.5 Stations were provided at intervals along the line so that trains travelling in opposite directions could pass one another; this action was known as a train crossing. There were 2 types of station, the most common being warrant stations that required addressees to operate the local signalling system to effect a crossing. The other type of station was known as an interlocked station, where the signalling system was remotely monitored and operated from train control. Compared with the number of warrant stations installed cross the network, there were only a small number of interlocked stations. Seddon was classified as a warrant station.

1.3.6 To assist train controllers in the issue of track warrants, a computer-based system called the Track Warrant Assisted Computer System (TWACS) was provided. The train controller could pre-prepare track warrants in TWACS based on their expected plot of the next stage of a train journey. The plotting, using time and distance parameters, was accomplished on a train control diagram provided at each desk.

1.3.7 TWACS was programmed to prevent the preparation of a track warrant for an opposing or following train if another had already been prepared and/or issued for any portion within the same limits. When issuing a track warrant to an addressee, the train controller mostly relayed the details by radio[7], but in the uncommon event of a failure to any part of the radio system, the details could be relayed by telephone. The addressee transcribed the details onto a prepared form, then read back the information to the train controller as a confirmation check. The addressee had no knowledge of other track warrants other than information passed verbally from train control or through listening to track warrants being issued to other addressees within the geographic radio channel area they were operating in.

[6] The generic term for recipients certified to work with a track warrant.
[7] The radio system was an extensive shore-to-cab system that enabled 2-way communication between train controllers and field operating staff over most of the rail network in New Zealand.

1.3.8 The signalling system at warrant and interlocked stations operated independently of each other because main lines in track warrant control territory were not track circuited[8] between stations. This meant that, unlike the centralised traffic control system for instance, it was not possible to display train movements on visual display units in train control. Train controllers were reliant on verbal communication with addressees to monitor the progress of trains and vehicles.

Operating arrangements

1.3.9 Warrant stations were equipped with a signalling system that provided minimal coverage of track circuiting. The system comprised an arrival signal located at the entrance to the station with an associated set of motorised points, located beyond the arrival signal.

1.3.10 Four trailing indicators were installed at the exits from both ends of the loop and main line. Unlike signals, the trailing indicators only confirmed to addressees that the points were correct for the intended movement. In all circumstances, a track warrant had to be obtained before passing any of the indicators.

1.3.11 A limited length of track circuiting existed at each station. The circuiting generally started about 800 m before the arrival signal and extended along the main line to the opposite point at the other end of the station (see Figure 3). The arrival signals were interlocked with the track circuits. The arrival signal displayed a caution, normal speed aspect on a train's approach if the circuiting was unoccupied and both points were in the normal position. The signal could be passed, without stopping, if the track warrant included specific instructions to berth on, or travel along the main line.

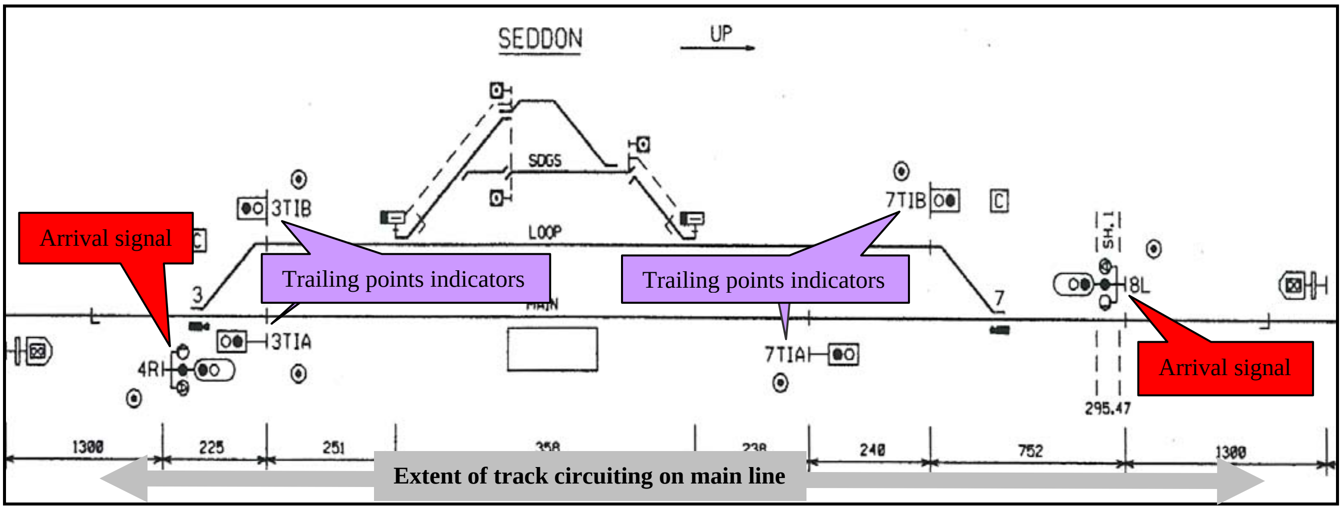

Figure 3
Signalling arrangements at Seddon (not to scale)

1.3.12 If a train or vehicle were scheduled to berth on the loop in accordance with the track warrant instructions, the addressee would bring their train or vehicle to a stop at the arrival signal, irrespective of the indication it was displaying. The addressee would then operate a pushbutton to reverse the points. The points would remain in the reverse position for a defined period of time to allow the addressee to re-board the train or vehicle and drive into the loop.

1.3.13 After passing the arrival signal, the addressee was required to stop before the trailing indicator if the track warrant terminated at that station.

1.3.14 The crossing sequence of Train 723 and Train 720 at Seddon is described in Figure 4.

[8] An electrical device using the rail in an electric circuit, which detects the absence/or presence of trains on a line.

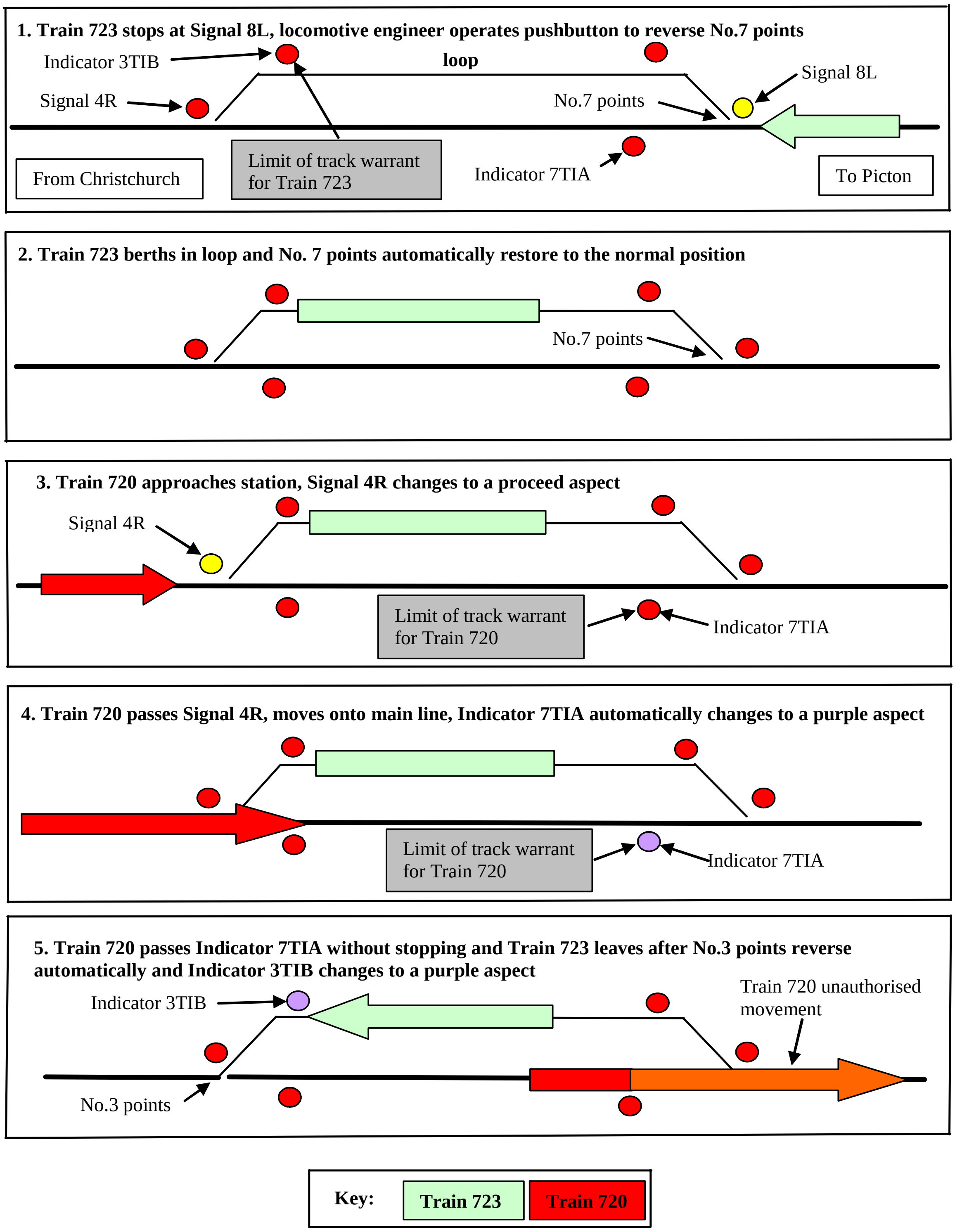

Figure 4
Crossing sequence for Train 723 and Train 720 at Seddon (not to scale)

1.4 Locomotive event recorder data

1.4.1 The data from the event recorder system installed on DFT7077 on Train 720 was downloaded and made available for analysis. The vigilance response data for the journey segment from about the time the train was travelling through Oaro (south of Kaikoura) at about 0115 to Seddon showed the following (see Figure 5):

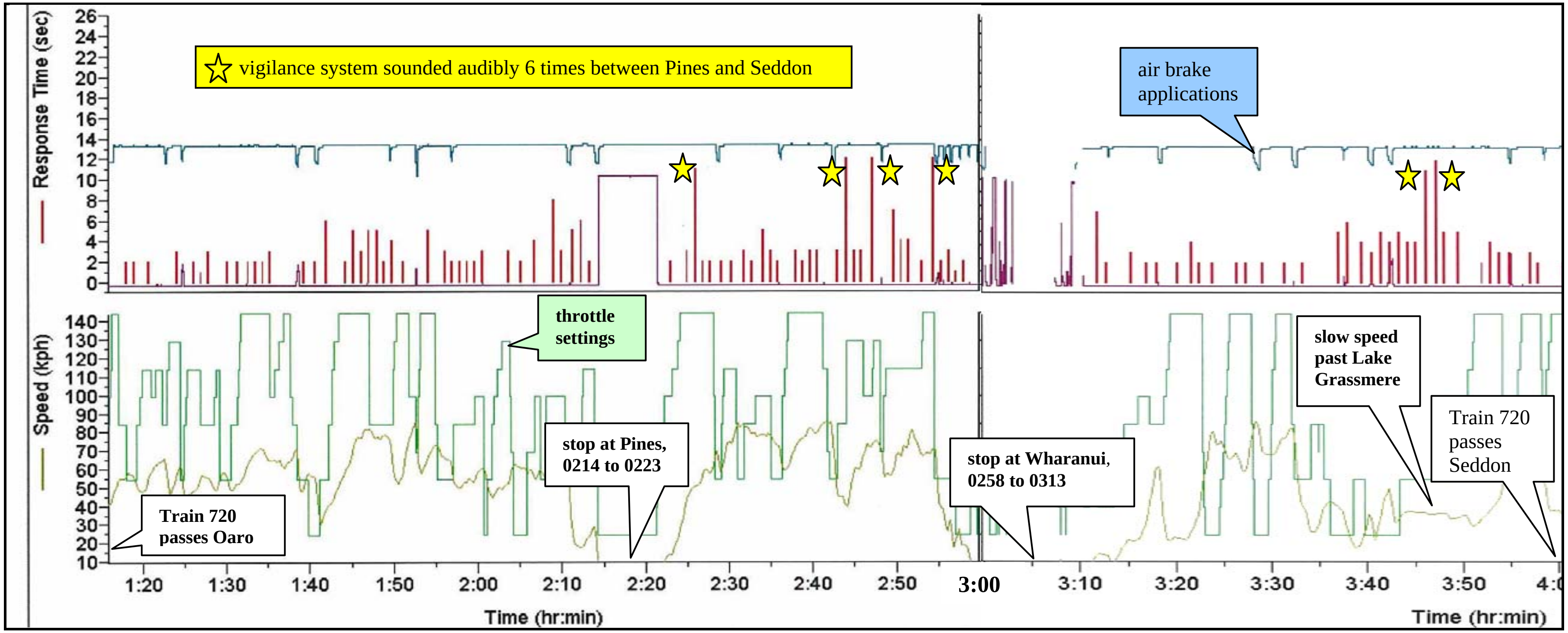

Figure 5
Train 720 event recorder data between Oaro and Seddon (not to scale)

1.4.2 The vigilance response data for the journey segment from Seddon to Vernon showed the following:

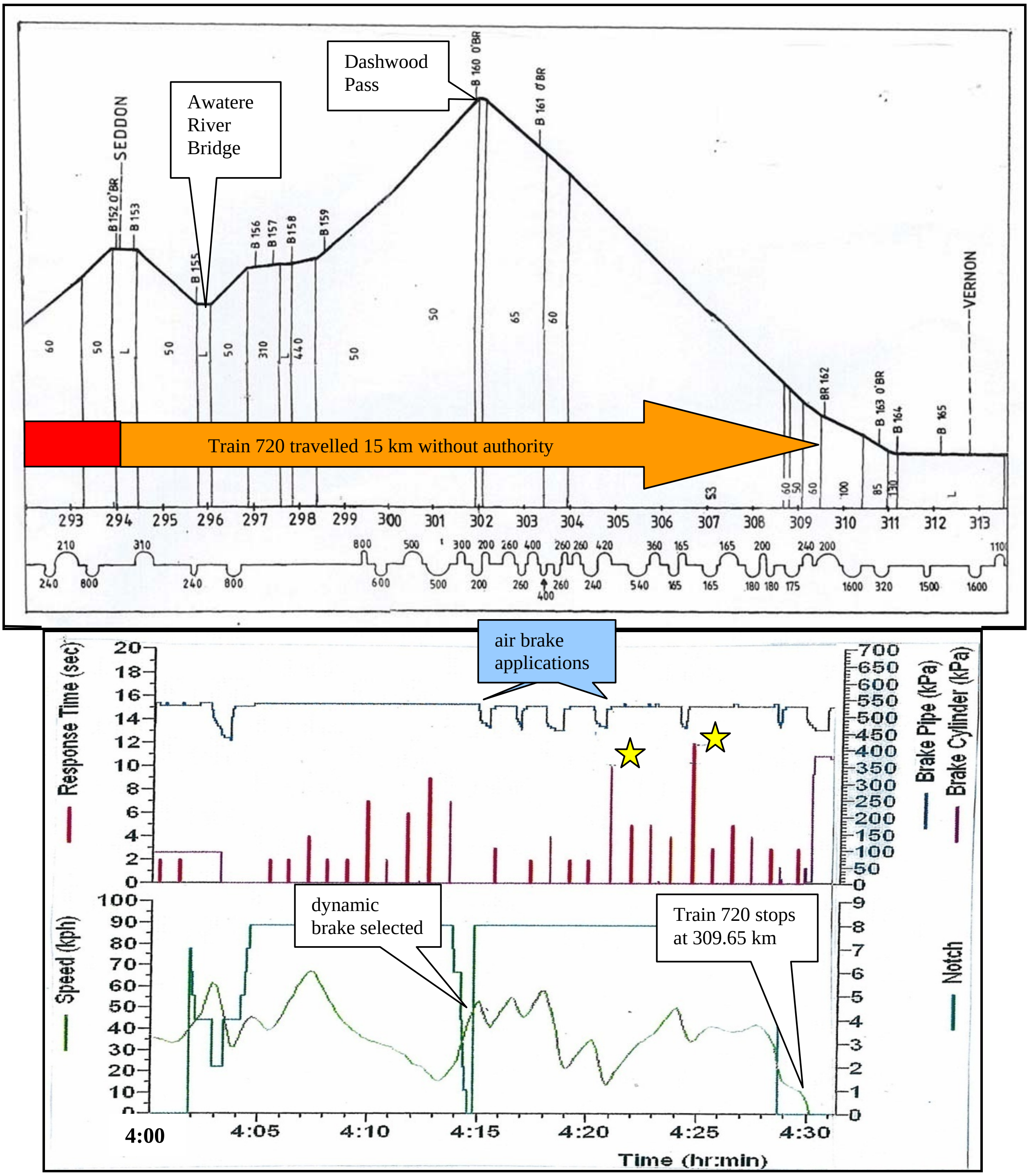

Figure 6
Gradient and alignment profiles between Seddon and Vernon at top;
Train 720 event recorder data compared over same distance at bottom (neither graph is to scale)

1.5 Sleep disorders

Sleep apnoea

1.5.1 Sleep apnoea is one of a number of sleep related breathing disorders and is characterised by pauses in breathing during sleep. These episodes, called apnoeas, last long enough so one or more breaths are missed, and occur repeatedly throughout sleep. For some individuals who snore profusely the airway can close. They continue to sleep even though they struggle to breathe, until the need to breathe overcomes the need to sleep (which it always will at some point) and they come out of deep sleep into a lighter sleep.

1.5.2 In most cases the individual does not wake right up. The change from deep sleep to light sleep is enough to allow the muscle tone to return to the airway so it can reopen, often with a loud gasp. This could happen hundreds of times a night. The standard definition of any apnoeic event includes a minimum 10-second interval between breaths, with either a neurological arousal (3-second or greater shift in electroencephalogram frequency) or a blood oxygen de-saturation of 3-4% or greater, or both.

1.5.3 Clinically significant levels of sleep apnoea are defined as 5 or more events of any type per hour of sleep time and are mostly diagnosed with an overnight sleep test called a polysomnogram. There are 3 distinct forms of sleep apnoea:

- central. Breathing is interrupted by the lack of effort in central sleep apnoea and is representative in 0.4% of cases
- obstructive. Breathing is interrupted by a physical block to airflow despite effort and is representative in 84% of cases
- complex. This describes a transition from central to obstructive features during the events themselves and is representative in 15% of cases.

1.5.4 Regardless of apnoeic type, individuals with sleep apnoea are rarely aware of having difficulty breathing, even upon awakening. Sleep apnoea is recognised as a problem by others witnessing the individual during episodes or is suspected because of its effects on the body. Symptoms may be present for years, even decades without identification, during which time the sufferer can become conditioned to the daytime sleepiness and fatigue associated with significant levels of sleep disturbance.

1.5.5 Obstructive sleep apnoea is the most common form of sleep-disordered breathing. Since the muscle tone of the body ordinarily relaxes during sleep, and since, at the level of the throat, the human airway is composed of walls of soft tissue, which can collapse, it is easy to understand why breathing can be obstructed during sleep. Mild, occasional sleep apnoea, such as many people experience during an upper respiratory infection, may not be important, but chronic, severe obstructive sleep apnoea requires treatment to prevent sleep deprivation and other complications.

1.5.6 Individuals with decreased muscle tone, increased soft tissue around the airway and structural features that give rise to a narrowed airway are at high risk of obstructive sleep apnoea. Sleep apnoea is present in about 5% in the ordinary population. This percentage increases to about 15% in the ordinary population for people 50 years and older. Men are more typical sleep apnoea sufferers, although the condition is not unusual in women and children. Shift workers have an increased tendency to suffer from sleep apnoea. Common symptoms include loud snoring, restless sleep, and sleepiness during the daytime.

1.5.7 Research has shown that sleep apnoea causes:

- daytime sleepiness
- attention capacity deficits
- reduced information processing speed
- short term memory span
- decrements in vigilance and performance.

Diagnostic options and treatment for sleep apnoea

1.5.8 Specialised medical treatment for sleep apnoea is available at 'Sleep-Well' clinics in Auckland, Wellington and Christchurch.

1.5.9 Besides the polysomnogram test, another test, known as an oximetry which measured oxygen intake and heart pulse, is less invasive and requires a clip to be worn on a little finger overnight. The recorded data is then downloaded to a central computer and the results obtained can provide an early diagnosis. This test normally follows the asking of some simple questions relating to whether they have been told that they snore and whether they get sleepy during the day.

1.5.10 Restorative treatment includes the use of a continuous-positive air pressure device which is worn over the nose and mouth while sleeping. The device was initially developed for the treatment of sleep apnoea in 1981 and delivers a stream of compressed air at a prescribed pressure. Long term treatment may also involve individual lifestyle changes, such as avoiding alcohol or muscle relaxants, losing body weight, maintaining physical fitness, sustaining proper dietary habits and quitting cigarette smoking.

The locomotive engineer's medical diagnosis

1.5.11 In this instance, the locomotive engineer underwent a series of extensive medical examinations during a lengthy post-incident stand-down period. He scored Epworth sleepiness results of 13 and 12, four-months apart by an otolaryngologist and a sleep medicine expert. Both of these scores indicated excessive sleepiness. The sleep medical expert concluded that the locomotive engineer was suffering from the effects of mild obstructive sleep apnoea.

1.5.12 After medical treatment and reassessment for the diagnosed sleep disorder, the locomotive engineer returned to full-time driving duties in December 2007, relinquishing all other work related responsibilities at the same time. During the rehabilitation period, he acquired a continuous-positive air pressure device for his personal use. It was not reported that the locomotive engineer was suffering from any other medical condition.

1.5.13 The locomotive engineer's loss of awareness prompted a close look at the role of sleep deprivation and fatigue in this incident. The Transport Accident Investigation Commission researched international papers covering the effects of sleep reduction on attention quality, and also engaged Professor Philippa Gander PhD, Director of the Sleep/Wake Research Centre at Massey University in Wellington to assist in determining whether any sleep disorder or fatigue could have contributed to this incident. The comments on these factors are made later in the analysis section of the report.

Major international incidents attributable to sleep disorders

1.5.14 The Sleep Well clinic's website stated that sleep disorders had been directly implicated in several major disasters around the world. Some well-known examples were:

- the Exxon Valdez oil tanker spillage in Alaska
- the Challenger space shuttle accident in the United States of America (USA)
- the Chernobyl nuclear power plant explosion in Russia
- the Bhopal chemical spillage in India.

1.6 Fatigue

1.6.1 Fatigue can be defined as a progressive loss of mental and physical alertness that could result in uncontrolled sleep. Lack of sleep because of a sleep disorder, sleeping at different times of the day, mental stress or high mental workload will quickly result in mental fatigue. A person can become increasingly inattentive while trying to concentrate on tasks. As fatigue increases, short-term memory becomes less effective and the person may forget vital information[9].

1.6.2 Fatigue is used as a catch-all term for a variety of different experiences, such as physical discomfort from overworking a group of muscles, difficulty concentrating, difficulty appreciating potentially important signals, and problems staying awake. In the context of an investigation, fatigue is important if it potentially reduces efficiency, erodes the safety margin, or otherwise impairs cognitive or physical performance.[10]

1.6.3 Every aspect of human performance can be degraded by sleep loss and sleepiness, including physical and mental performance. Once sleep debt or fatigue builds, only sleep can maintain or restore performance levels.

1.6.4 Lack of sleep and a reduction in sleep quality are the main factors affecting levels of fatigue, mood, health and, ultimately, performance. Persons lose sleep either by reducing a single sleep period by a large amount (acute sleep loss) or by building up a sleep debt over time by reducing sleep on consecutive sleep periods (accumulated sleep loss). Attempting to sleep at times when the body is less inclined to do so will disrupt sleep. The duration of the sleep period will be shorter and the structure will be altered, resulting in further lost sleep[11].

1.6.5 Most people who are fatigued do not realise how tired and impaired they are and disregard the warning signs of fatigue. Major indicators of severe fatigue include:

- incorrect reading of equipment
- missing a reference point
- not remembering the last command given
- giving wrong commands
- degraded mental abilities (including memory, decision making and perception)[12].

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[9] Source - Fatigue Management Guide for Canadian Pilots, Transport Canada, 2003.
[10] Source - A Guide for Investigating for Fatigue, Transportation Safety Board of Canada, 1997.
[11] Source - Fatigue Management for Canadian Pilots, Transport Canada, 2003.
[12] Source - Fatigue Management Guide for Canadian Pilots, Transport Canada, 2003.

Circadian rhythm

1.6.6 A circadian rhythm is an approximate daily periodicity, a roughly 24-hour cycle in the biochemical, physiological or behavioural processes in human beings. In addition to an afternoon low point, the rhythm reaches its natural nadir between about 0300 and 0600 when the body's temperature and metabolic rate drop. The body's temperature reaches its lowest at 0430; about 2½ hours before habitual wake time (see Figure 7).

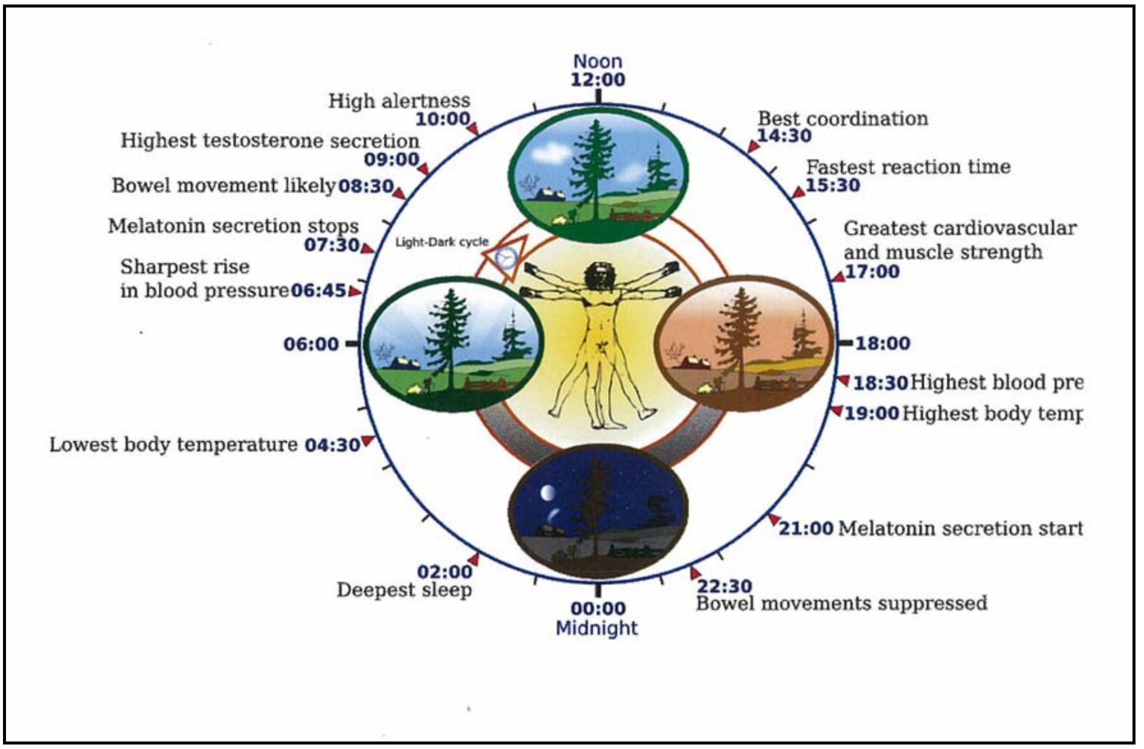

Figure 7
The circadian rhythm

1.6.7 Modern research has shown that the circadian rhythm period resets itself daily to the 24-hour cycle of the Earth's rotation. Working shifts across the 24-hour clock conflicts with a person's circadian rhythm of wakefulness and sleep, degrading that person's physical and mental wellbeing.

1.6.8 A paper entitled "Fatigue Management in the New Millennium"[13] stated:

- Night work – as the amount of night work increases, so does the amount of sleep that must be attempted at biologically inappropriate times. Sleeping 'out of synch' with the body's biological clock [Circadian rhythm] results in reduced duration and quality of sleep. This in turn reduces the restorative value of sleep obtained.

- Research data indicates that shift workers obtain significantly less sleep than those who are not shift workers. Moreover, the quality of that sleep is also significantly reduced. Sleep loss during night work is typically 1 – 3 hours per day. Furthermore, sleep deprivation can accumulate across a block of shifts, which leads to higher fatigue.

- Taken together, both employers and employees have clear responsibilities with respect to managing fatigue. The basic responsibilities of both parties relate to ensuring that adequate sleep can be obtained between shifts so that fatigue does not reach dangerous levels during shifts. Thus, lack of sleep causes fatigue and sleep allows recovery from fatigue.

[13] Author: Professor Drew Dawson, University of South Australia Centre for Sleep Research.

- Research by the Centre for Sleep Research at the University of SA [South Australia] has clearly demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. That is, significantly delayed response and reaction times, impaired reasoning, reduced vigilance [and] hand-eye co-ordination.

International concern about fatigue

1.6.9 The following information is included to show the level of concern in the USA, although train crew rostering policies differ between that country and New Zealand.

1.6.10 The National Transportation Safety Board (NTSB), the equivalent of the Transport Accident Investigation Commission, has long been concerned about the issue of operator fatigue in rail transportation and stressed its concerns in investigation reports issued throughout the 1970s and 1980s. Its investigations into freight train collisions found that on one occasion the crew members had had only 2 hours' sleep in the preceding 22-24 hours and none of the crew had eaten a meal for at least 13 hours. In a second incident the locomotive engineer had been able to depress and release the vigilance pedal in his sleep preventing the automatic stopping of his train.

1.6.11 In 1989, the NTSB issued 3 recommendations calling for research, education, and revisions to existing regulations affecting the area of fatigue. These recommendations were added to the NTSB's "Most Wanted" list in 1990, and have remained on that list since then. The NTSB's 1999 safety study of efforts to address operator fatigue continued to show that this problem was widespread. The NTSB said that operating a vehicle without the operator's having adequate rest, in any mode of transport, presented an unnecessary risk to the travelling public.

1.7 Locomotive safety systems

Radio system

1.7.1 A network of very-high-frequency (VHF) radio repeaters and a train control supervisory system are provided to enable locomotive engineers to communicate with train control. There are 6 variants of radio equipment used on locomotives and most of the equipment is equipped with 4 channels. The channels are allocated as follows:

channel 1	used between locomotive engineers on different trains; signal box controllers; train examining and infrastructure staff
channel 2, 3 and 4	train control to locomotives (allocated geographically)

1.7.2 The VHF radio system is equipped to scan all 4 channels and does this in rapid cycles. The radio will stop scanning and lock onto a channel when a signal is received on any of the 4 channels.

1.7.3 A voice recording system installed in train control records all VHF radio transmissions made on channels 2, 3 and 4 between locomotive engineers and train control. Some signal boxes are equipped with voice recording equipment to record channel one radio transmissions between locomotive engineers and signal box controllers. There is no voice recording equipment installed on locomotives.

Vigilance system

1.7.4 A vigilance system was an arrangement that required the locomotive engineer to take positive action at frequent intervals to ensure crew responsiveness in order that safe train driving was maintained. The system was designed to record crew responsiveness to indicator lights and/or audible warnings within a maximum period of 70 seconds.

1.7.5 The national rail system standards required the driving cabs of all rail vehicles to be equipped with a vigilance system acceptable to Ontrack, and the rail operating code stated that vigilance systems were fitted for the protection of crews.

1.7.6 The system installed on DFT7077 was a Kaitiaki integrated vigilance, event recorder and speed measuring system, which recorded in detail locomotive activities and responses to vigilance stimuli. The system was an "alerter" system that monitored the vigilance of the locomotive engineer. The format comprised fixed time cycles, being:

- 50 seconds, ± 3 seconds, to the warning light illuminating (visual stimulus)
- a further 10 seconds, ± 2 seconds, to the vigilance whistle sounding (audible stimulus)
- a further 10 seconds, ± 2 seconds, to the locomotive's air brake system applying.

1.7.7 The vigilance cycle was reset when the locomotive engineer pressed a cancellation button. To manage the distractive impact of the vigilance system, the cycle was also automatically reset whenever the locomotive engineer made a change to either the air brake or throttle control settings or sounding the locomotive whistle.

1.7.8 If the vigilance system was not acknowledged at the expiry of an audible warning, the air brake, commonly referred to as the penalty brake, would apply in the same manner as an emergency brake application, and in conjunction with a power reduction, the train would be stopped.

1.7.9 Brake pipe air pressure was continually monitored by a transducer, and when a reduction of air pressure from 550 kilopascals to 350 kilopascals in less than 10 seconds was detected, an emergency brake application was also made. A result of these occurrences was that the vigilance system automatically sent an alarm to train control via the radio system containing the locomotive identifier.

Vigilance system alarm-train control response

1.7.10 When the visual and audible alarm was received in train control, the train controller was required to make immediate radio contact with the locomotive engineer to enquire about the nature of the emergency. If the nature of the emergency meant that the train controller could not make voice contact with the locomotive engineer within 2 minutes, the train controller initiated the calling out of field personnel to travel to the train by the most expeditious means.

Tranzlog locomotive event/locomotive engineer vigilance recorder system

1.7.11 KiwiRail (and its predecessors) were progressively upgrading the event recorder systems fitted to its freight train locomotive fleet. The new system, developed in New Zealand, was known as the "Tranzlog" event recorder (see Figure 8) and was replacing older event recorder systems such as the Kaitiaki system.

Figure 8
A Tranzlog-type event recorder

1.7.12 The Tranzlog system held about one month's compressed data and downloading of that data was accomplished by connection to a portable computer loaded with the appropriate software. Tranzlog was currently programmed to operate in exactly the same way as the Kaitiaki and the older electronic systems, except that Tranzlog was a computer based system and was therefore fully programmable to allow for flexible and adaptable vigilance control monitoring.

1.7.13 Tranzlog was capable of recording the following data:

- locomotive speed
- direction of travel
- throttle setting and brake application movements
- brake pipe air pressure
- main reservoir air pressure
- headlight, ditch light and train whistle operation
- locomotive engineer response to the vigilance system.

1.7.14 Integrated with the Tranzlog system was a global positioning system (GPS) that was able to verify, at defined short term intervals, the location of a train. The first Tranzlog unit was fitted to a New Zealand locomotive in September 2003, and by June 2007 three hundred and forty units had been installed across the New Zealand rail industry's operating fleet.

1.7.15 The manufacturer said that the Tranzlog software could be upgraded with the capability to transmit a radio alarm to train control at the same time as an audio alarm sounded in a locomotive cab and prior to the penalty brake application. The estimated cost to upgrade each unit was about $100.

1.7.16 The manufacturer said that a real-time "loco agent" had been developed that could be thought of as each locomotive's own dedicated centrally located train control system. It was envisaged that a train controller could set the limits of a track warrant into the loco agent, and the agent could monitor the locomotive and make sure it did not overrun the limit location. More importantly the location could be stored within Tranzlog (live downloaded or from a fixed location trigger) and automatically advise the locomotive engineer of proximity to that limit that then required action or else the penalty brake could be applied. As at December 2008, there were 170 loco agent-equipped Tranzlogs installed in KiwiRail's mainline locomotive fleet.

1.7.17 Some Tranzlogs already have activated GPS location-based actions. For example when a DX locomotive arrives at Otira heading east to Christchurch, at a point before the locomotive enters the steeply graded 8.5 km long Otira tunnel a damper is automatically operated by the Tranzlog to give increased cooling to the locomotive while running through the tunnel. The damper is then automatically closed when the locomotive leaves Arthur's Pass.

1.7.18 Additionally, Tranzlogs have an in-built modem connected to the Telecom network which transmits position and other locomotive status information back to a central server.

Project Kupe

1.7.19 Project Kupe was a project managed by Ontrack's signals and telecommunications group to replace the current train-control-to-train-crew radio system that provided national coverage of the majority of the main lines and principle branch lines. The project, launched in 2005, incorporated GPS tracking capability to pinpoint the locations of trains in track warrant control territories. This project would also improve safety for Ontrack's infrastructure staff as it is intended to install GPS capability in its maintenance vehicles that have rail mode capability.

1.7.20 On 8 December 2005 and as a result of rail occurrence report 05-105, track occupation irregularity at Kokiri, the Commission recommended to the Chief Executive of Ontrack that he develop a safety defence system for track occupations in single-line automatic signalling areas in line with systems that provided a similar level of safeguard in other signalling areas.

1.7.21 On 16 December 2005, Ontrack replied in part:

> Ontrack accepts this recommendation, and considers that it will be satisfied through the development and implementation of Project Kupe. This project will see GPS data for all locomotive and other self propelled rail vehicles being available to National Train Control.
>
> Project Kupe Phase 1 has been approved for implementation. Installation of Ontrack infrastructure to support the transmission and display of GPS position information will be completed by the 3rd quarter of 2006. The installation of GPS receivers on Toll's rail vehicles and Ontrack's hi-rail vehicles is expected to take two to three years.

1.7.22 On 19 June 2008, Ontrack advised as follows:

> We are currently testing a rewritten TWACS system. Once in use there is a second stage to the project (at this stage not approved) to provide the following:
>
> - Display of vehicle location on the track warrant control schematic
> - Integrate with centralised traffic control for coordinated clearing of starting signals into track warrant control territory
> - The transmission of Track Warrants digitally to vehicles on the rail network.
>
> Once track warrants are transmitted in electronic format the potential to monitor the vehicle location against the limits of authority is gained. Some work will need to be put in to ensure appropriate safety certification (unless designed carefully there will be reliance on these alerts).
>
> The functionality is on the Kupe roadmap, however at this stage finance has not been approved and more work is required to complete the rollout of the Kupe vehicle equipment.

1.8 Positive train control

1.8.1 On 8 September 2008, the NTSB published a railroad accident brief following a rear-end collision between 2 freight trains in California that occurred on 10 November 2007. The NTSB found that the 2 crew members did not comply with stop indications on any of 3 signals as their train approached a stationary train because they were likely asleep. The 2 crew members did not survive the collision (see Figure 9). The NTSB also found that a lack of a positive train control system contributed to the collision. It was estimated that the cost of damage was US$ 2 million.

Figure 9
Freight train collision in California

1.8.2 Following the head on collision between a commuter passenger train and a freight train in California on 12 September 2008 that resulted in the deaths of 25 persons, a bill that set a deadline of 2015 for the implementation of positive train control technology on the US railroads was signed into law by the President on 16 October 2008. Amongst its provision, the law provides funding to help pay for the development of positive train control technology and limits the number of hours locomotive engineers can work each month.

1.8.3 Positive train controlling works by having an on board system receiving the parameters of a train movement authority issued by train control. The on-board positive train control system also uses GPS positioning data to calculate speed in order to create braking curves to ensure the train (with all its variables) stays within the boundaries of the movement authority parameters. When a possible violation of the authority is determined by the on-board system, the locomotive engineer is warned. If the train speed is not brought within the braking curve within a certain time, the positive train control system intervenes by making an emergency brake application.

1.8.4 Types of positive train control system are in widespread use in some European countries and there are small pockets of different positive train control systems in some sectors of the North American railroad system. Positive train control could work across all types of signalling/ operating system, such as the equivalent of track warrant control, centralised traffic control and double-line automatic signalling systems as used in New Zealand.

1.9 Locomotive engineer management

Medical standards

1.9.1 Within Toll Rail's (and its predecessors) safety system, there was a policy document called "Company procedures Q/022 medical standards". The document was first issued on 30 June 1997 and was last updated on 4 March 2004.

1.9.2 The document outlined that periodic medical assessments and associated procedures were to be conducted on existing employees engaged in safety-critical and other operational roles The document also included specific standards for the locomotive engineer's role, in part:-

Locomotive Operating Employees
General Examinations • Prior to issue of License to Operate • Under 40 – Every ten (10) years after the issue of the license • 40-50 – Every three (3) years; • 50+ - Annually

1.9.3 During these examinations the locomotive engineer was required to fill out a paper-based questionnaire called an "Epworth sleepiness scale" which was used internationally to diagnose sleep disorder. The questionnaire was classed as a passive test in that it asked questions relating to the individual's chance of dozing while undertaking rest activities such as watching television, sitting and reading a book and watching a movie in a theatre. It was known that dozing during such passive activities generally unmasked sleepiness in an individual. This written questionnaire did not include any input from a locomotive engineer's family.

1.9.4 During one of these examinations, and if a locomotive engineer was diagnosed for a sleep disorder such as sleep apnoea for the first time, they would be classified as a category A standard. This meant that the locomotive engineer was not considered fit for locomotive operating tasks. After treatment and upon specialist medical review and opinion, the locomotive engineer would then be classified a category B standard which would allow them to return to locomotive operating tasks.

1.9.5 Toll Rail said that from a workforce of about 500 locomotive engineers, about 6 were referred to a sleep clinic annually. The majority of locomotive engineers eventually returned to locomotive operating tasks after treatment for obstructive sleep apnoea.

Alertness management training

1.9.6 Toll Rail had an alertness management training presentation that it rolled out to its locomotive engineers in 2002. New locomotive engineers who joined the company after 2002 received alertness management training as part of their induction training. Toll Rail classified completed training in alertness management as a certification that then required a bi-annual on line assessment to remain current.

1.9.7 The training presentation included, in part, the following:

- fatigue was a safety concern in the rail industry and the training document concluded that it was important for individuals to develop strategies to maintain alertness
- excessive changes to the pattern of a roster that was designed to reduce fatigue would impact on safety
- following a number of fatigue-related incidents in the early 1990s, forward rotation of shifts, limiting the number of night shifts worked per week and more specific standby hours were introduced by Tranz Rail[14]
- there were 2 windows when the human body was most vulnerable to maximum sleepiness. Those windows were between the hours of 0300 and 0500, and between 1500 and 1700. Research conducted by Tranz Rail showed that 50% of sleep-related incidents that occurred in the 6-year period between 1990 and 1995 occurred between the hours of 0400 and 0500
- the training document suggested that a locomotive engineer stop the train and take a walk around as a strategy in preventing fatigue.

1.9.8 The training presentation concluded by saying that sleepiness could have severe consequences. It stated that staff should think about how they could improve their approach by considering and implementing lifestyle changes. Staff should not wait for an incident to occur because the locomotive engineers involved in a series of incidents between 2000 and 2002 (refer Section 1.10 in this report) did not expect incidents to happen to them. Finally the presentation said that people are different and because of this, they should tailor strategies identified in the presentation to suit their own needs.

1.9.9 The team leader locomotive engineer passed an "online" alertness management reassessment on 6 September 2005.

Crew resource management training

1.9.10 In 2002, Toll Rail developed a crew resource management (CRM) training presentation which it rolled out to its locomotive engineers. New locomotive engineers, who joined the company after 2002, received CRM training as part of their induction training. Toll Rail classified completed training in CRM as a certification that then required a bi-annual online assessment to remain current.

[14] Company name of the integrated rail business at that time and predecessor to Toll Rail.

1.9.11 The training presentation included, in part, the following:

- to the question of what is CRM, it said that 2 heads were better than one
- in its definition of a crew, the presentation said that within Toll Rail, many people physically worked on their own
- the key requirements for good team work within a crew were seen as staying tuned to what was going on around you and creating an environment where people could challenge without fear of retaliation
- one of the 3 basic rules of CRM was being prepared to intercede even if you were a third party
- an example of change of mindset was from "it's not my job" to "we are all responsible for safety"
- CRM would help to improve safety and create an environment where "challenge" was accepted.

1.9.12 Both the team leader locomotive engineer and locomotive engineer of Train 723 passed an "on line" CRM reassessment on 6 September 2005.

Reference to CRM in published rail occurrence reports

Report 05-102, track warrant control irregularity, Otane, 18 January 2005

1.9.13 On Tuesday 18 January 2005 a track warrant irregularity occurred when a track warrant was issued to the locomotive engineer of Train 627 at Otane authorising his train to proceed to Takapau to cross opposing Train 626.

1.9.14 Train 626 was scheduled to shunt at Takapau and, while berthed on the loop waiting to commence the shunt, the locomotive engineer heard the train controller issue a track warrant to the locomotive engineer of Train 627 at Otane authorising him to travel to Takapau to cross Train 626. The locomotive engineer of Train 626 knew that he was already in possession of a track warrant authorising him to advance to Waipukurau to cross Train 627 and realised that a conflicting track warrant had been issued. He notified the train controller immediately.

1.9.15 Had the locomotive engineer of Train 626 not challenged the train controller, Train 627 would have departed from Otane with the locomotive engineer in possession of a track warrant authorising him to cross Train 626 at a station beyond that to which Train 626 was already authorised to travel for the same crossing, creating a potential head-on collision situation.

Report 07-110, collision between express freight Train MP2 and work Train 22, Ohinewai, 19 June 2007

1.9.16 On Tuesday 19 June 2007, express freight train MP2 was travelling between Huntly and Te Kauwhata when it struck a gantry crane from work Train 22 which was stationary and working on the adjacent Down Main line with its cranes fouling the Up Main line. The gantry rotated on impact and struck the operator, knocking him from the wagon and in to the passing train. The operator was fatally injured.

1.9.17 The accident occurred when the cranes they were operating were fouling the adjacent Up Main line in the path of the approaching MP2 because the person-in-charge was under the erroneous belief that protection for Work Train 22 had been arranged covering both main lines.

1.9.18 Although 2 persons associated with the Work Train 22 rail recovery operation were aware that Train MP2 was due to pass on the adjacent main line, which the work train was fouling during the rail recovery, neither had communicated this to the person-in-charge or taken defensive action to prevent the collision.

1.9.19 Among the findings from this investigation was that the quality of CRM, including management of resources at different locations such as the train control centre, locomotive cabs and track work sites was of an inconsistent standard across the rail industry and contributed to the accident.

1.9.20 Arising from this investigation it was recommended to the Chief Executive of the New Zealand Transport Agency on 6 October 2008 that he address the following safety issue:

> The quality of crew resource management to achieve outcomes in this case, including the management of resources at different locations such as the train control centre, locomotive cabs and track work sites, sometimes using different communication methods, was of a poor standard, and previously published occurrence reports, as well as other, still open investigations, indicate that the standard of crew resource management across the rail industry is not adequate. (026/08)

Rostering policy

1.9.21 Toll Rail's operating manual said that the object of a properly constructed working roster was to avoid, as far as possible, the need for an employee to report for duty when not rostered to do so and to provide the best possible shift patterns given the work available.

1.9.22 Rosters were to be constructed on the basis of work being performed at a depot and covered a 14-day fortnight with the first week referred as the "A week" and the second week as the "B week". Rosters were based on the timetabled services, shunting services, plus other authorised and necessary depot work. New rosters were to, where possible, preserve the existing roster pattern and sequencing.

1.9.23 Train timetables were reviewed constantly to meet the needs of customers. Changes to work patterns and practices were reviewed to ensure the company remained a cost-competitive and efficient operator. Toll Rail had 3 separate processes for managing variations to a roster. The extent of the proposed changes was the factor that determined which process was followed.

1.9.24 A crew coupling, which provided a return journey for each locomotive engineer to their home depot, was a primary component of a roster. Toll Rail stated that economics and safety were factors in establishing each crew coupling.

Personal needs breaks

1.9.25 Personal needs breaks of 30 minutes were scheduled in the crew coupling/timetables of shifts in excess of 4 hours. Where possible the personal needs break was to be taken midway through the shift, and where suitable facilities existed away from the locomotive. The actual taking of personal needs breaks was arranged between the locomotive engineer and the train controller on the day.

Picton depot roster

1.9.26 The Picton locomotive engineer's roster, which included 12 locomotive engineers and the team leader locomotive engineer, had been reduced from an authorisation of 13 persons to 12 persons (11 locomotive engineers and the team leader locomotive engineer) on 6 May 2007, six days before the incident. Toll Rail management had reduced the establishment following a review of the work content and capacity for managing annual leave, sickness and other types of less frequently used authorised leave absences. There was no reduction in the number of train and shunting services required to be crewed at this time.

1.9.27 The following table shows the fortnightly rostered hours, hours worked and extra work periods worked by the 12 locomotive engineers during the 3 fortnights prior to the incident. An extra work period was additional to the roster and locomotive engineers could decline these extra duties for personal reasons without any recrimination. Note that Easter weekend fell on the weekend of 7 April and ANZAC Day fell during the first week of the fortnight ending 5 May, which had the effect of reducing the number of trains running during those times.

	Fortnight ending 7 April			Fortnight ending 21 April			Fortnight ending 5 May		
	rostered hours	hours worked	extra work periods worked	rostered hours	hours worked	extra work periods worked	rostered hours	hours worked	extra work periods worked
1	80.35	80.35		82.40	43.35		78.25	78.25	
2	82.40	52.35	1	78.25	90.00	2	80.40	92.25	1
3	78.25	85.15		80.40	81.25		82.40	76.50	
4	80.40	44.40		80.35	81.50		77.10	94.55	2
5	80.00	102.55	3	80.00	94.00	1	79.00	102.45	2
6	77.10	79.00		79.00	89.25	1	83.40	82.05	
7	79.00	61.20		80.20	79.25		83.40	88.50	1
8	80.20	74.15		80.45	annual leave		80.25	82.35	
9	83.40	81.50	1	83.40	83.25		78.00	60.25	
10	80.45	accident comp.		80.00	accident comp.		80.00	accident comp.	
11	80.00	87.15	1	80.00	78.35		79.00	81.30	
12	worked by team leader locomotive engineer						not filled		

1.9.28 During 2008, the locomotive engineer authorisation level at Picton depot was restored to 12 locomotive engineers and one team leader locomotive engineer from the previous authorisation level of 11 locomotive engineers and one team leader locomotive engineer applicable from 6 May 2007.

The team leader locomotive engineer roster

1.9.29 The team leader locomotive engineer had his own fortnightly roster. In the 3 fortnights prior to the incident, the locomotive engineer worked the following hours and extra work periods:

Fortnight ending	Rostered hours	Hours worked	Extra work periods worked
7 April	80.05	89.10	2
21 April	80.05	103.20	2
5 May	80.05	annual leave	

During the fortnights ending 7 and 21 April, the team leader locomotive engineer did not perform any safety assessments.

1.9.30 The following table details the old roster (in black and which applied during the fortnights in paragraph 1.9.27) and the new roster (in red) that applied from 6 May 2007:

	Old roster "A week"	New roster "A week"	Old roster "B week"	New roster "B week"
Sunday	off	off	off	Off
Monday	0900-1830	team leader 8 hours	0900-1830	1200-2020
Tuesday	1200-2020	1200-2020	team leader 8 hours	Off
Wednesday	1200-2020	1200-2020	off	off
Thursday	1435-0025*	1435-0025*	off	1130-2015
Friday	1855-0445*	1855-0445*	team leader 2300-0700	team leader 8 hours
Saturday	1935-0420*	1935-0420*	off	off

*Next day.

1.9.31 On the roster for "A week" beginning 6 May 2007, the team leader locomotive engineer worked the following actual hours:

"A week"	Roster	Actual hours worked
Sunday 6 May	off	off
Monday 7 May	Team leader 8 hours	0900-1800 (drive work train)
Tuesday 8 May	1200-2020	1200-2020
Wednesday 9 May	1200-2020	1200-2020
Thursday 10 May	1435-0025	0800-1600 (team leader duties)
Friday 11 May	1855-0445	1855-0930#
Saturday 12 May	1935-0420	off

Note: the roster is shown in red for comparison.
Incident occurred at 0400 on Saturday 12 May.

1.10 Previous Commission investigations into similar incidents

Between 2000 and 2002

1.10.1 The Commission investigated 5 occurrences between 2000 and 2002 that had similarities to the current incident. The occurrences were:

- Rail Occurrence Report 00-115, derailment of a freight train near Westmere following a high speed entry into a restricted speed curve on 22 September 2000
- Rail Occurrence Report 00-117, derailment of a freight train near Kai Iwi following a high speed entry into a restricted speed curve on 26 November 2000
- Rail Occurrence Report 00-121, collision between 2 freight trains near Middleton when one of the trains passed a signal at stop on 8 December 2000
- Rail Occurrence Report 02-107, collision between a freight train and a stationary shunting locomotive when the train was berthing at New Plymouth on 29 January 2002
- Rail Occurrence Report 02-116, derailment of a freight train near Te Wera following a high speed entry into a restricted speed curve on 26 July 2002.

1.10.2 The common theme among these 5 investigations was the loss of awareness and attention by locomotive engineers succumbing to micro sleeps or longer duration sleeps because of various fatigue related reasons.

1.10.3 On 19 June 2001, in its report 00-115, the Commission recommended to Tranz Rail that it revise the operation of the vigilance system to provide a better defence against short-duration micro-sleeps (019/01). On 25 June 2001, Tranz Rail advised that it had accepted the recommendation.

1.10.4 The recommendation was then repeated in reports 00-117, 00-121 and 02-107. In response to report 02-107, Tranz Rail advised that it was still progressing with the implementation of the recommendation.

1.10.5 Safety recommendation 019/01 was again repeated in report 02-116 and on 16 January 2003, Tranz Rail advised that a project leader had been appointed by its mechanical maintenance supplier to provide variable time cycle and speed cycle alternatives of the vigilance system for review by the locomotive engineer's council comprised of company and union representatives.

1.10.6 In August 2003, Toll Rail stated that alternative vigilance system options had been assessed in conjunction with the rail and maritime transport union delegates. Between November 2003 and February 2004, four alternative systems were trialled and locomotive engineers surveyed for feedback. During May 2004, the survey results were analysed, and as a result, further specification was developed for an alternative system. In November 2004, the alternative system was developed for trial in early 2005.

1.10.7 With the roll out of the Tranzlog event recorder in its freight locomotive fleet and self-propelled passenger rolling stock, Toll Rail said that this had provided an opportunity to re-visit the project. Some background functionality had been provided in the Tranzlog software and some further work to firm up the specification for further software changes was needed to provide a prototype for further analysis.

In 2005

1.10.8 In Rail Occurrence Report 05-117, express freight Train 211 passed a signal at stop Rangitawa with the locomotive engineer in a micro-sleep because of fatigue on 12 May 2005. Rangitawa was an interlocked station within a centralised traffic control signalling area monitored in train control.

1.10.9 The locomotive engineer recalled falling asleep on 2 occasions prior to reaching Rangitawa. In this instance the vigilance system installed on the locomotive was a non-computerised system that did not have the capability for continual dynamic alertness monitoring.

1.10.10 Following a radio call from a locomotive engineer on an opposing train, the train controller saw on his visual display unit that Train 211 had occupied an unauthorised track section and immediately radioed the locomotive engineer. The locomotive engineer was instructed to stop his train when he responded. Train 211 had travelled about 540 m into the unauthorised track section.

1.10.11 This incident occurred at 0410 and followed a deterioration of the locomotive engineer’s alertness following an accumulation of sleep debt. The sleep debt had accumulated because of non-medical reasons.

1.10.12 On 17 June 2008, Toll Rail advised as follows:

> Further development of an enhanced vigilance system is to be progressed but it should be understood that a straightforward solution may be difficult to achieve.
>
> For instance the specification determined during the 2005 review would not have prompted stopping the train and alerting train control. The parameter was set at a nominal ratio of 5 "vigilance whistle" cancellations within a total of 7 "vigilance whistle" cancellations to detect instances of more prevalent noise activated cancellations/micro sleeping detected after incidents or during the random extraction process.
>
> The event recorder information from this incident, which has a much less frequent ratio, and others for which fatigue has been identified as a factor will be reviewed to establish if a more conservative specification should be applied. Obviously this review will need to ensure the parameters are not tightened up to an extent that the end result will mean trains are stopped and alerts generated because a locomotive engineer is focusing on other normal cab related tasks.
>
> This conflict is likely to add some complexity to arriving at the ideal specification.
>
> However, in addition to the above we have maintained contact with an Australian railway company who are participating in a joint project with a supplier who have developed a system monitoring vigilance through glasses that measure tiny invisible pulses of light to detect eye and eyelid movement. If drowsiness is detected the system provides for in cab alerts to be initiated. Integration into the vigilance system is being developed.

2 Analysis

Introduction

2.1 Train 720 overran its track warrant limits by 15 km in a 28-minute period with no recognition by the locomotive engineer. Fortuitously the only opposing traffic at the time was Train 723 berthed in the loop at Seddon; otherwise the potential for a head-on collision would have been real. This report examines the issue of fatigue and related factors, and the effects they had on the locomotive engineer. It also looks at some of the defences, either in place or that could have been in place that may have prevented the track warrant overrun, or detected it earlier.

2.2 On the issue of sleep deficit and fatigue and their relevance to human performance a number of international papers on the subject were researched, which are listed in the Appendix. Specific reference is made where relevant in this analysis.

Fatigue

2.3 Figures 5 and 6 on pages 8 and 9 depicting the relationship between stimulus events and driver vigilance show a classic pattern of the locomotive engineer reacting to the vigilance alarm and other events requiring his attention, then slipping into a pattern of low vigilance during periods of low stimulus; that is, when the level of input needed to drive Train 720 was reduced.

2.4 Professor Gander, Director of the Sleep/Wake Research Centre at Massey University examined the descriptors of the incident and found that they were consistent with the locomotive engineer experiencing a period of extreme sleepiness, probably including multiple inadvertent micro-sleeps, before and after passing Seddon. A micro-sleep is a brief nap that lasts for a few seconds, when the brain ceases to provide visual information or sounds until the person is re-awakened, so they effectively disengage from the environment. Micro-sleeps are a manifestation of extreme physiological sleepiness. Without adequate recovery sleep on a regular basis, physiological sleepiness builds progressively to the point where micro-sleeps are inevitable.

2.5 The incident occurred during the first night shift following 4 day shifts, and before that the locomotive engineer had been on leave for 2 weeks. The first point is that from a rostering perspective there was ample time to sleep. Although moving from day shift to night shift was avoided during roster creation because of the disruption caused, there are ways to minimise the effect, such as attempting to sleep before starting a shift. However, the locomotive engineer did not plan to sleep during the day before his night shift, so regardless of any other factors, he was going to have been awake for about 21 hours before the end of his shift. This long period of wakefulness would naturally be extended if his return train was running late, which it was on this occasion. In medical terms this would have resulted in an acute sleep loss, something that was within the locomotive engineer's control. Added to this was his lack of proper liquid and solid sustenance during the shift and not taking a personal needs break.

2.6 The second point to consider was the quality of the sleep. The locomotive engineer suffering from sleep apnoea would have reduced the quality of what sleep he did have, so it was possible that he was suffering from a cumulative sleep debt, although this had largely gone unnoticed by him or those around him because the effect had become normalized over time.

2.7 The third point to consider was the time of day the incident occurred: right in the lowest point in the body's circadian rhythm when the urge to sleep is at its greatest.

2.8 The locomotive engineer had received training in alertness management in train operations and in lifestyle choices to minimise the effect of shift work, and thus reduce the effects of fatigue. While the second and third points were outside his control, the first point was, as were other choices such as taking breaks and eating to maintain alertness.

2.9 It was clear that the locomotive engineer's sleep apnoea had not been identified during any of his company medical tests. Regardless, the medical tests that the locomotive engineer underwent did not include reports or observations from those close to him. Because those suffering from sleep apnoea are usually not aware of their condition, extending the examination to include those who observe the person sleeping could prove useful in the early detection of any problem. A safety recommendation covering this safety issue has been made to the Chief Executive of the New Zealand Transport Agency in this report.

Rostering

2.10 The roster change that applied from 6 May 2007 contained only minor sequential changes to the daily duties of the team leader locomotive engineer. Both the old and new rosters had an equal number of days allocated for his team leader and train driving responsibilities. Although the reduction by one locomotive engineer did not affect the team leader's roster, it was apparent to him that he and the other locomotive engineers were going to be requested to work more hours to cover planned and unplanned leave periods. Also the backlog of safety assessment duties concerned the team leader locomotive engineer sufficiently for him to present his concerns to management. In view of the subsequent reinstatement of locomotive engineer resourcing levels at the Picton depot, these concerns have since been addressed.

2.11 The table in paragraph 1.9.27 shows the hours worked by the locomotive engineers. On average they were not excessive. Comparatively though, 2 of the locomotive engineers seemed to be shouldering a higher share of extra work periods than the others and this was most likely a case of their being more willing and able to undertake these additional shifts. In the team leader's case though, his acceptance to work the extra work periods was probably driven more by a sense of duty than for any other reason. Ultimately though, the team leader could have declined the changes that were asked of him during the week leading up to the incident, but instead he was able to rearrange his own roster to allow time to resume his delegated team leader responsibilities.

Understanding the locomotives engineer's actions

2.12 Both locomotive engineers acknowledged the exchange of channel one radio information between them before Train 723 had berthed in Seddon, but because the subject of the call then turned to the execution of the berthing arrangements, neither could recall any reference being made to the limits of the track warrant held by Train 720. The locomotive engineer of Train 720 could not recall making a further channel one radio call as he approached the warning board, and neither could the locomotive engineer of Train 723 recall hearing such a call. The radio system on Train 723, even though it was on scan, would have picked up the channel one call from Train 720. Therefore the call was probably not made, thus denying the locomotive engineer of Train 720 the opportunity to remind himself of the warrant limits so close to Seddon.

2.13 The locomotive engineer immediately acknowledged that he had overrun his track warrant limits when the train controller transmitted the base call. He had been in possession of the track warrant from Pines for 100 minutes and this would have given him ample opportunity to remind himself of the limits during the channel one calls approaching the 3 warrant stations between Pines and Seddon. Because of his mounting level of fatigue, some of those calls, like the one approaching Seddon, may have been missed.

2.14 In spite of the locomotive engineer's level of fatigue and sleepiness, what he accomplished during the next 28 minutes in driving Train 720 beyond Seddon showed a good standard of compliance with speeds through the many tight-radius curves. The data from the event recorder showed that the locomotive engineer made appropriate use of the throttle and the dynamic/air brake to maintain the correct speed. The locomotive engineer would have been required to monitor his speed constantly to ensure the train was under full control through the many curves, particularly during the descent from the Dashwood Pass summit.

2.15 Because the locomotive engineer regularly worked the route and Trains 737/720 on a Saturday morning in particular, he would have instinctively known that no further train crossings were likely on the remainder of the journey to Picton. The schedule had not recently changed and he was working what he was used to.

2.16 The anticipation of reaching the automatic signalling territory at Vernon and then arrival at Picton, from what he described, was at the forefront of his mind. Once he had passed Train 723 at Seddon, it would not have been unusual for him to relax a little because he would not have expected any further train crossings. How he was able to continue to drive his train for the next 28 minutes while in an apparent state of decreased vigilance is described in a number of research papers.

2.17 Researchers from the Emory University School of Medicine in Atlanta USA, and the La Sapienza University in Rome, Italy, presented findings that could help understand the locomotive engineer's performance in this instance.

2.18 The paper by the Emory University School of Medicine said that micro-sleeps and lapses in cognition increased with sleep loss. Sleep deprivation studies repeatedly showed a variable (negative) impact on cognitive performance and motor function as the propensity to sleep increased.

2.19 The paper by the La Sapienza University and the Aeroporto Pratica di Mare of Rome showed an overall slowing of reaction time across 24-hour wakefulness sessions, indicating a linear decrease of vigilance with increasing fatigue. Two main features of sleep loss seen were a decrease in vigilance and a decrease in cognitive performance. However, the vigilance decrease did not seem to affect attention-orienting mechanisms, suggesting that the 2 systems were independent of each other. A person's orienting network was seen to allocate attention selectively to a potentially relevant area of the visual field. Orienting can be reflexive, such as when a sudden target event directs attention to its location, or it can be voluntary.

2.20 To satisfy themselves, the researchers suggested that the orienting mechanisms could be affected differently by a reduction in the vigilance level. It was said that when sleep loss was manipulated, 2 potential sources of influence could affect vigilance decrease: one was sleep loss per se (one contributor being sleep apnoea) and the other was the circadian rhythm (in this instance the incident occurred at 0400, a known low point in that rhythm). The aim of the study was to evaluate the effects of 24 hours of prolonged wakefulness on visuospatial attention.

2.21 The results showed a significant vigilance decrease across the 24 hours of sustained wakefulness, with a more relevant worsening in performance during nocturnal hours; the data was similar to previous results, indicating a gradual impairment of performance when a moderate sleep loss (e.g. Casagrande et al. 1997; Gillberg and Kerstedt 1998) or night-time work (e.g. Casagrande et al. 1999) occurred. The result suggested that the 2 systems, vigilance (in this instance the routine of operating the locomotive's controls) and orienting (where am I and what do I need to do beyond the routine?) were independent of each other and did not interact, at least in the conditions of the experiment.

2.22 In this incident, it was possible that the locomotive engineer suffered from a decrease in visuospatial attention while Train 720 was nearing and passing through Seddon, but maintained an adequate level of vigilance for his train-driving routine up and down the steep, winding gradients of the Dashwood Pass. The locomotive engineer turned on his cab light and waved to his colleague on Train 723, but appears not to have realised this was a cue also to reduce the locomotive's throttle setting in preparation for stopping the train and obtaining an ongoing track warrant.

2.23 In other words, seeing Train 723 stopped in the loop at Seddon appears to have invoked an orienteering network response to acknowledge the existence of the train, but not that its existence meant that the locomotive engineer of Train 720 should be stopping as well. The next response may have been invoked by the trailing indicator displaying a purple indication, telling him that the points were correctly set for the main line and his train movement over them.

2.24 Humans cannot, however, operate in a cognitive vacuum; that is, with absolutely no awareness of where they are or what they are doing. For this reason it could not be entirely ruled out that with his level of fatigue and sleepiness he forgot that his track warrant went only to Seddon, and reverted back to a previous learned behaviour whereby the timetabled crossing with Train 723 was at Vernon, this in spite of acknowledging the crossing had just taken place at Seddon. This might also explain why he saw reaching Vernon as the time he was nearly home and could "relax", even though from there he still had to follow the signals of the centralised traffic control territory, negotiate several stations and level crossings and, finally, negotiate the steep grade down into Picton.

Alertness monitoring

2.25 Throughout the return journey from Picton to Ferniehurst, a distance of 409 km, the locomotive engineer only left his cab on 3 or 4 occasions, minimising his face-to-face contact with anyone else. Besides that human contact, the other interactions he had were the verbal communications with the train controller and other locomotive engineers in compliance with track warrant control procedures. The break at Wharanui on Train 720 would very likely have revived him to some extent, but it was clear that the revival only lasted a short period.

2.26 During the return journey from Pines to Vernon, the vigilance system was cycling through, activating visual and audible alarms with the associated event recorder logging the locomotive engineer's responses. Throughout recent history, the vigilance system has essentially remained unchanged. On the other hand, while event recorders have been in existence for some time, they have evolved. The role of an integrated vigilance and event recorder system in the modern rail industry with single-person train crewing practices is crucial. Modern event recorder systems are effective in monitoring crew responsiveness, but an equally important role that such systems can play is at the "back end" of what to do with the recorded data.

2.27 In this instance the system was recording a pattern of deteriorating alertness, but alarms were not being transmitted outside the locomotive cab to say, train control where action could have been taken to address the matter. On 6 occasions prior to reaching Seddon, and one, possibly 2 occasions after leaving Seddon, the vigilance system had cycled into the audible alarm status.

2.28 The first that anyone else would have become aware of a problem was if there were no response during a full 10-second sounding of the audible alarm. However, throughout the journey of Train 720, that situation never occurred and the train controller would have been unaware of the locomotive engineer's situation. Instead, the locomotive engineer was being repeatedly aroused by the audible alarm a matter of seconds after it sounded, yet he was not alert enough to appreciate that he had reached the limits of his track warrant coming into Seddon.

2.29 The first audible alarm occurred at 0226, three minutes after Train 720 had left Pines, and the last audible alarm occurred at about 0425, a few minutes before the train controller sent the base call that eventually resulted in the locomotive engineer stopping the train. During that 2-hour period, Train 720 had travelled a distance of about 85 km with a locomotive engineer being aroused from micro-sleeps by the audible alarm in his cab.

2.30 It was apparent from Toll Rail/KiwiRail comments that there seemed some reluctance to utilise the capabilities of the modern Tranzlog event recorder for the purpose of alerting train control when such situations had developed, or were developing. Despite accepting a safety recommendation 7 years previously, and even though the Tranzlog system was now the predominant event recorder system in use, the industry had not made good use of this tool to help prevent fatigue related incidents in spite of the serious accidents and incidents to which fatigue was related. A safety recommendation covering this safety issue has been made to the Chief Executive of the New Zealand Transport Agency in this report.

Crew Resource Management

2.31 The locomotive engineer of Train 723 would have been well aware that Train 720 was required to stop at Seddon. His decision to not initiate radio contact with Train 720 as it travelled past his locomotive and ask about his perceived irregular train handling meant that the last defence, the application of good CRM, was not used.

2.32 The locomotive engineer of Train 723 was experienced and although the locomotive engineer of Train 720 was his team leader, they were performing the same roles in driving heavy freight trains in the early hours of a weekend morning. Nothing would have been lost in challenging the team leader, or enquiring on channel one if all was okay or, if not, enquiring of train control about Train 720's track warrant. Either would have been preferable to Train 720 being later involved in a serious occurrence.

2.33 This incident demonstrated the critical importance of having a strong CRM culture that encourages challenges being directed at someone who holds a senior position to the initiator. Such actions should be accepted as part of everyday operational practice, with immediate feedback that closes out the communication loop without leaving any doubt or guilt, particularly with the initiator. Because reference has been made to the issues surrounding the promotion and ongoing practices of CRM in several past and concurrent Rail Occurrence Reports, including 07-110 and 07-113, the Commission will not be making a safety recommendation covering this issue in this report.

Project Kupe/Positive train control

2.34 The small number of interlocked stations historically located in track warrant control areas gave a window of opportunity for train controllers to monitor the locations of trains. On this occasion, the train controller had no way of monitoring the unauthorised journey of Train 720 beyond Seddon. If Seddon had been an interlocked station, the train controller would have had the means to see the overrun incident occur and could have intervened at that time, but he would have had to be monitoring that train's progress and not dealing with other issues during those moments.

2.35 Project Kupe's planned GPS-based monitoring of rail vehicle will provide another defence against track warrant overruns, but it will be limited by the reliance on the human train controller to monitor train/vehicle progress in track warrant control territory. The Commission is concerned that Project Kupe has not been implemented 2½ years from the start date of December 2005 and that some of the project detail has yet to be finalised and funding approved. Until Project Kupe in some form is implemented, the risk of collision between rail vehicles remains unnecessarily high.

2.36 The Commission considers that track warrant control, centralised traffic control and double-line automatic signalling areas could benefit from the additional safeguards offered by Project Kupe's capabilities. The track circuiting inherent in the 2 automatic systems was designed to prevent 2 trains occupying the same track circuited area under normal speed conditions but overruns, such as those at Middleton and Rangitawa (refer Section 1.10 in this report), occurred even though the train movements were governed by track-circuited signalling and interlocking systems at these locations.

2.37 Previous investigations in New Zealand, and the current overseas investigations mentioned in this report, show the risk to human life and property when safe train operation is degraded when fatigue and related issues, such as distraction, affect the alertness of the locomotive engineer. This risk is not reduced with track circuited signalling systems such as centralised traffic control because investigations have shown that red signals on their own do not stop trains.

2.38 The Commission shares the view of the NTSB that a positive train control system would provide a better defence against inadvertent overruns in any signalling system. The Commission proposes through separate safety recommendations to the Chief Executive of the New Zealand Transport Agency that the safety benefits, versus cost, of Project Kupe be assessed as well as whether the terms of reference should include positive train control capability that would not only alert the locomotive engineer and/or the train controller, but automatically intervene and regulate the speed or movement of the train/rail vehicle to prevent or minimise any overrun.

3 Findings

Findings are listed in order of development and not in order of priority.

3.1 Train 720 exceeded the limits of its track warrant by about 15 km over a 28-minute period, when the locomotive engineer had sufficient cognitive functioning to drive his train with a reasonable level of skill but limited spatial awareness of his surroundings owing to the effects of extreme sleepiness owing to the length of time without sleep, and possibly cumulative fatigue.

3.2 The locomotive engineer was suffering from extreme sleepiness because:

- he had remained awake for the 11½ hours before starting his shift which meant that he was awake for 20½ hours prior to the incident
- the quality of his sleep was affected by the medical condition obstructive sleep apnoea
- the time of day was at the low point of his circadian rhythms when the urge for sleep is at its greatest
- he had not had adequate food intake to sustain such a long period of duty and had not taken a personal needs break.

3.3 Good CRM between the locomotive engineer of Train 720 and that of 723 could have prevented or minimised the extent of the track warrant overrun when the trains crossed at Seddon.

3.4 The event recorder on Train 720 clearly showed a pattern of low vigilance with the locomotive engineer over a distance of 85 km and for a period of 2 hours. Information of this type could have been used to alert train control of his condition had the equipment been used to its full potential.

3.5 Vehicle movement monitoring by train control has the capability to reduce the risk of incidents occurring across the network if the technology, integrated with existing systems such as TWACS, is used to its full potential.

3.6 Positive train control, where train speed and movement are automatically regulated when position and speed parameters are exceeded, has the potential to reduce significantly the risk of incidents and accidents, more so than train monitoring only.

4 Safety Recommendations

Safety recommendations are listed in order of development and not in order of priority.

4.1 On 19 February 2009, the following safety recommendations were made:

4.1.1 The modern computerised Tranzlog vigilance system is capable of increased alertness monitoring beyond that currently exploited. The Commission recommends the New Zealand Transport Agency takes action to address the safety issue whereby for about 5 years after the technology had become available that could reduce the risk of fatigue related occurrences; the rail industry has not exploited this opportunity (002/09).

4.1.2 The Commission recommends the New Zealand Transport Agency takes action to address the safety issue whereby locomotive engineer medical tests procedures that could increase the likelihood of detecting sleep and other associated disorders do not currently include the use of modern diagnostic monitoring systems (003/09).

4.1.3 The development of Project Kupe system has the potential to reduce the risk of collision on the network but, due to resource and funding restraints without a cost/safety benefit analysis being undertaken, the project has extended out by 2½ years and has still not been approved. The Commission recommends the New Zealand Transport Agency takes action to address the safety issue (004/09).

4.1.4 The terms of reference for Project Kupe do not currently include further development into full positive train control capability. The Commission recommends the New Zealand Transport Agency takes action to ensure that any project to enhance train control functionality results in a progressive move to achieving positive train control (005/09).

4.2 On 9 March 2009, the Chief Executive of the New Zealand Transport Agency replied as follows:

> Thank you for your letter dated 19 February 2009 containing the above final safety recommendations.
>
> We intend to work closely with the relevant rail industry participants with an aim to implementing and closing these recommendations as soon as practicable. We are unable to give you an exact timeframe, as this will depend on the outcome of discussions we have with these participants.
>
> When these discussions are concluded and the appropriate evidence has been gathered we will be in touch with TAIC with a view to closing these recommendations.

Approved on 19 March 2009 for publication

Hon W P Jeffries
Chief Commissioner

5 Appendix

5.1 During the course of this investigation, the Commission researched several international papers covering the subject of the effects of sleep reduction on attention quality The following papers were researched:

- Orienting and alerting: effect of 24 hour of prolong wakefulness by M Casagrande, D Matella and E Di Pace from the “La Sapienza” University and M Casagrande, F Pirri and F Guadalupi from the Centro Sperimentale di Volo, Reparto Medicina Aeronautica e Spaziale, Aeroporto Pratica di Mare, both entities based in Rome, Italy and published online on 25 November 2005.
- Neurocognitive consequences of sleep deprivation by J Durmer and D Dinges from the Emory University School of Medicine based in Atlanta, USA and dated March 2005.
- Effects of sleep reduction on spatial attention by F Versace, C Cavallero, G De Min Tona, M Mozzato and L Stegagno, from the Department of Psychology, University of Trieste and Department of General Psychology of Padua, Italy and published online on 22 June 2005.
- Effects of sleep deprivation on lateral visual attention by A Kendall, M Kautz, M Russo and W Killgore from various research centres in the USA military and received on 9 June 2005.
- Sustained attention performance during sleep deprivation: evidence of state instability by S Doran, H Van Dongen and D Dinges from the Division of Sleep and Chronobiology, Department of Psychiatry and Centre for Sleep and Respiratory Neurobiology, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, USA and dated 2001.
- Increased cerebral response during a divided attention task following sleep deprivation by S Drummond, J Gillan and G Brown from the Department of Psychiatry, University of California, San Diego, USA and received on 29 November 2000.
- Executive function in sleep apnoea: controlling for attention capacity in assessing executive attention by E Verstraeten, R Cluydts, D Pevernagie and G Hoffmann from the Department of cognitive and Physiological Psychology, Laboratory for CNS research: Cognition, Neuropsychology and Sleep, Vrije University/Free University Brussels; Department of Pneumology, Centre for Sleep-wake Disorders, University Hospital Ghent and Laboratory for Sleep Disorders, University Hospital Brugmann, Brussels, all based in Belgium and accepted for publication in January 2004.

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

07-113	express freight Train 239, wagons left in section at 514.9 km, between Te Awamutu and Te Kawa, 22 September 2007
07-110	collision, express freight Train MP2 and work Train 22, Ohinewai, 19 June 2007
06-110	passenger Train 4045, uncontrolled movement, between Britomart and Quay Park Junction, 9 October 2006
06-108	EMU Passenger Train 9268, struck slip and derailed, between Wellington and Wadestown, 26 August 2006
07-101	express freight Train 736, derailment, 309.643 km, near Vernon, 5 January 2007
05-123	empty passenger Train 4356, overran conditional stop board without authority following an automatic air brake irregularity, Meadowbank, 6 October 2005
05-116	collapse of Bridge 256 over Nuhaka River, Palmerston North-Gisborne Line, 6 May 2005
05-124	express freight Trains 834 and 841, collision, Cora Lynn, 20 October 2005
06-112	loss of airbrakes and collision, Tram 244, Christchurch, 21 November 2006
06-102	SA/SD passenger Train 4306, braking irregularity, between Westfield and Otahuhu, 31 March 2006
06-101	diesel multiple unit passenger Train 3163, fire in diesel auxiliary engine, Manurewa, 15 March 2006
05-127	Mainline shunting service M52, track occupation irregularity, Te Rapa, 27 October 2005
05-120	Express freight Train 142, runaway wagons, Mercer, 1 September 2005
05-128	Diesel multiple unit Train 3056, passenger injury, Papatoetoe, 31 October 2005
05-125	Taieri Gorge Railway passenger Train 1910, train parting, Dunedin, 28 October 2005
05-118	Express freight Train 245, derailment, Ohingaiti, 27 July 2005
05-115	Empty passenger Train 2100, train parting and improper door opening, Ranui, 1 April 2005
05-108	Diesel multiple unit passenger Train 3334, fire, Auckland, 23 February 2005

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