RAILWAY OCCURRENCE REPORT
R98V0100

MAIN TRACK DERAILMENT

CANADIAN PACIFIC RAILWAY
FREIGHT TRAIN NO. 981-31
MILE 59.1, NELSON SUBDIVISION
CRESTON, BRITISH COLUMBIA
31 MAY 1998

Transportation Safety Board of Canada

Bureau de la scurit des transports du Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Railway Occurrence Report

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Report Number R98V0100

Synopsis

On 31 May 1998, at approximately 0455 Pacific standard time, Canadian Pacific Railway freight train No. 981-31, travelling from Cranbrook, British Columbia, to Nelson, British Columbia, on the Nelson Subdivision encountered a roadbed depression at Mile 59.1 near Creston, British Columbia, and derailed three locomotives and eight gondola cars. Approximately 90 cubic metres of silver/lead concentrate was released from the derailed gondola cars. The fuel tanks from one locomotive were punctured and approximately 21,000 litres of diesel fuel was released. Most of the silver/lead concentrate and diesel fuel was recovered. There were no injuries.

The Board determined that the track failed due to saturation and failure of the subgrade fill. Contributing factors were the record rainfall, the performance of the drainage system, the steep sidehill slope, and the high susceptibility of the subgrade fill material to water changes.

Ce rapport est également disponible en français.

1.0 Factual Information

1.1 The Accident

Freight train No. 981-31 (the train) departed Cranbrook, Mile 0.0 of the Nelson Subdivision[1], at approximately 0155 Pacific standard time (PST)[2], travelling westward and destined for Nelson, Mile 137.8.

The trip between Mile 0.0 and Mile 59.1 was without incident. As the train negotiated a left-hand curve at Mile 59.0, the train crew observed that the subgrade ahead had collapsed and that the track was suspended above the depression. Three locomotives and four gondola cars (the first to the fourth from the head end) slipped down the embankment and came to rest at the bottom of the depression. The fifth car to the eighth car, all gondola cars, derailed on the right-of-way. Approximately 90 m^3 of silver/lead concentrate was released from four of the derailed gondola cars. The fuel tanks from one locomotive were punctured; approximately 21,000 litres of diesel fuel and about 200 litres of gear oil were released.

Both crew members were uninjured and were able to free themselves from the wreckage and initiate an emergency broadcast.

1.2 Damage to Equipment

Two locomotives and seven gondola cars were damaged beyond repair. One locomotive and one gondola car sustained major damage.

1.3 Other Damage

Approximately 150 feet of track was destroyed.

1.4 Personnel Information

The train crew consisted of a locomotive engineer and a conductor, both of whom were in the lead locomotive. They were qualified for their respective positions and met established fitness and rest standards.

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1 The Nelson Subdivision is operated by the Kootenay Valley Railway (KVR) which is an internal short-line railway owned by Canadian Pacific Railway.

2 All times are PST (Coordinated Universal Time (UTC) minus eight hours) unless otherwise stated.

1.5 Train Information

The train included 3 locomotives, 31 loaded cars and 58 empty cars. It was approximately 5,200 feet long and weighed about 5,400 tons.

1.6 Particulars of the Track

The track structure consisted of 132-pound jointed rail. The rail was laid on softwood ties with single-shouldered tie plates and was fastened with five spikes per tie plate. The ballast was crushed rock. All track components were in good condition.

At Mile 59.1, train movements are governed by the Occupancy Control System authorized by the Canadian Rail Operating Rules and supervised by a rail traffic controller located in Calgary. Between Mile 57.5 and Mile 63.2, the maximum authorized speed is 20 mph for freight trains.

Eastward Canadian Pacific Railway (CPR) freight train No. 984 passed this location approximately eight hours before the derailment. The crew did not note any track irregularities.

1.7 Occurrence Site Information

1.7.1 General

In the area of the derailment, the railway embankment slipped away leaving a void approximately 27 m long and 5 m deep.

The railway track in the derailment area was built (circa 1895) on a bench formed by an alternating sidehill cut and fill, 25 m above the flood plain of the Goat River, along the toe of a mountain slope. The site is located downslope of an alluvial cone situated between two rock outcrops in the mountain side. The mountain slopes are covered by a mature coniferous forest with some patches of deciduous vegetation. The lower part of the alluvial cone is a discharge area for water infiltration occurring on the upper part of the cone.

Indications of significant discharge and surface water flow were noted at several locations in the face of the slope above the track and from beneath some natural talus just below the track. The flowing water is captured in a ditch along the upside of the track and conveyed beneath the track through culverts. The closest culvert was located approximately 10 m east of the subgrade failure, and was carrying a large water flow. The culvert was partially impeded subsequent to the derailment; its condition before the failure is not known.

An examination of over 30 culverts and the ditches along the track, between Mile 58.0 and Mile 61.0, revealed the following:

- approximately half of the culverts were of small diameter, 30 cm and 45 cm;
- the inlets and/or outlets of eight culverts were partially plugged by ballast;
- two corrugated steel pipe culverts had partially crushed inlets; and
- in some areas, silt deposits were observed in the bottom of ditches, and water was ponding and penetrating the subgrade.

1.7.2 The Spilled Silver/Lead Concentrate

The four gondola cars, which slipped into the depression, spilled their contents down the embankment and into the flood plain of the Goat River. The spilled silver/lead concentrate was held in containment booms and was recovered by an environmental contractor. Silver/lead concentrate (UN 3077) is considered to be an environmentally hazardous substance in the low-to-moderate hazard range. Inhalation or contact with the substance may be harmful.

1.8 Weather

At the time of the derailment, the temperature was approximately nine degrees Celsius, with light easterly winds.

The amount of precipitation for the week before the derailment, recorded at the nearest meteorological stations to the derailment site, Creston (Mile 67.2) and Goatfell (Mile 45.6), is presented in Table 1. The figures, expressed in millimetres (mm), were obtained from the British Columbia Ministry of Forests.

	Day of Week	Creston	Goatfell
May 25	Monday	0.0	0.0
May 26	Tuesday	5.2	23.4
May 27	Wednesday	59.6	35.8
May 28	Thursday	0.3	21.5
May 29	Friday	0.0	0.0
May 30	Saturday	26.9	30.5
May 31[3]	Sunday	0.0	0.0
Total for the week		92.0	111.2

[3] Date of the derailment.

Table 1 - Precipitation during the week before the derailment (in mm)

Table 2 details the historical weather statistics for different durations and return periods[4]. They were compiled by Environment Canada for Cranbrook, the closest station for which historical data are maintained.

	Return Period		
Duration of Rainfall	5 years	50 years	100 years
One Day	30.4	50.0	55.7
One Week	53.7	90.2	100.8

Table 2 - Historical rainfall data for Cranbrook (in mm)

According to local residents, the rate of precipitation on 27 May 1998 was variable, intermittent in the morning and afternoon, and steady in the evening. The amount of precipitation recorded was confirmed by a farmer located near the derailment site; he noticed that the level on his livestock drinking trough was overflowing and had risen by at least 50 mm.

During the week of 25 May 1998, the rainfall recorded at Goatfell (111.2 mm) exceeded the 100-year return period. The amount recorded at Creston, during the same period (92 mm), exceeded the 50-year return period; the daily rainfall on Wednesday, 27 May 1998 (59.6 mm), exceeded the 100-year return period.

1.9 Recorded Information

The event recorder data from the lead locomotive revealed that the train was travelling at a recorded speed of 22 mph and that the speed suddenly dropped to 10 mph. There was no reduction in brake pipe pressure, indicating that an emergency brake application had not taken place.

1.10 CPR Track Inspection Program

1.10.1 General

The CPR track inspection program is undertaken to identify irregularities and to plan maintenance for the ongoing safe operation of trains. Transport Canada's (TC) Track Safety Rules (TSR) and CPR's Maintenance-of-Way Standard Practice Circular - Track (SPC) No. 32 provide the specifications for track inspections (regular and additional).

The Nelson Subdivision is divided into territories for track maintenance programs. The territory where the derailment occurred runs between Curzon (Mile 42.5) and Nelson (Mile 137.8). It is under the responsibility of

[4] The rainfall for a week that would be exceeded once in 100 years is called the one-week rainfall for a return period of 100 years.

a Track Maintenance Supervisor (TMS), who is assisted by two Assistant Track Maintenance Supervisors (ATMSs).

1.10.2 Regular Track Inspection

Regular track inspection specifications stipulate the individual responsible for performing the inspection, the frequency of the inspection, the methods of inspection, the items to be inspected, and the requirements for recording the inspection. Track inspection personnel may include a TMS, an ATMS or a qualified person pursuant to the TSR. The track around Creston must be inspected twice per week. Track inspections are usually carried out by a Hi-rail vehicle travelling at 20 mph.

The track maintenance foreman last inspected the track in the Creston area by Hi-rail on 27 May 1998, between 0700 and 1300; no irregularities were observed.

A track geometry car inspection of the area was last performed on 27 November 1997; no exceptions were noted at Mile 59.1.

1.10.3 Additional Track Inspections

CPR SPC No. 32 and the TSR call for additional track inspections during or subsequent to unusual weather conditions.

CPR SPC No. 32 states that:

> Additional track inspections may be required under conditions of:
>
> a) strong winds which may cause trees or other obstacles to fall on the track.
> b) heavy rain or snow or repeated freeze-thaw cycles which may cause high water, washouts, rock falls or mud slides.
> c) extreme hot or cold temperatures which may cause buckled track or rail pull-aparts.
> d) long dry periods coupled with track maintenance activities, or train operations which may cause fires.

The TSR describe the requirements for additional inspections under the section called Special Inspections:

> In the event of fire, flood, severe storm, or other occurrence which might have damaged track structure, a special inspection must be made of the track involved as soon as possible after the occurrence.

Similar specifications are also in use by other railways. For example, Canadian National (CN) SPC No. 3100 specifies that:

> Additional inspections will be ordered by the District Engineer or Track Supervisor whenever conditions arise that may endanger the safety of operation.

The local weather conditions in the Creston area are not formally monitored nor are they required to be. The assessment of the weather conditions is based on the local ATMS's own observations and from information they are able to gather in their immediate surroundings. It was noted that an ATMS, in an adjacent subdivision, was monitoring the weather through a direct link to the local Environment Canada stations.

Personnel stated that they were not restricted in any way from carrying out additional inspections when required. There was no additional inspection performed subsequent to the record rainfall on Wednesday, 27 May 1998.

1.10.4 Slope Stability Programs

1.10.4.1 Rock Slope Stability

In 1974, CPR established a rock slope stability inspection program based on annual inspections by the CPR Geotechnical Group staff or consultants. Subsequent to a previous derailment at Mile 111.0 of the Nelson Subdivision near Proctor, on 20 January 1995 (TSB report No. R95V0017), CPR complemented the program by routine rock patrols in advance of each train. During these patrols, local inspectors monitor hazardous locations and look for fallen rocks fouling the track.

At the time of this derailment, one ATMS on the Nelson Subdivision had received the rock slope stability training. The TMS, the second ATMS, and the two relieving track foremen performing track patrols had not received the training.

1.10.4.2 Soil Slope Stability

In 1997, CPR instituted a soil stability program to assess the subgrade and drainage conditions along most of the mainline routes. This program included a systematic identification of locations susceptible to soil slope instability and characterizations of slope angles, soil types, and drainage conditions. The Nelson Subdivision was not included in this program, as it is not a mainline route.

In addition, CPR and CN jointly developed, in 1997, a soil slope stability course entitled "Geotechnology for Railroaders." This course outlines the mechanisms, the site assessment and the mitigation methods involved in soil instability.

Both railways had begun to train their maintenance-of-way staff. Personnel on the KVR had not attended the course before this derailment.

1.10.5 Work Schedule

In the territory where the derailment occurred, the track inspection duties are shared between the two ATMSs. One ATMS worked from Sunday to Wednesday, and the other from Wednesday to Saturday. In the absence of both ATMSs, the inspection is conducted by a track maintenance foreman.

Rock patrols are performed on a daily basis in front of each train; on Sundays and Wednesdays, they are combined with the regular track inspection. Shift start and end times fluctuate, depending on train movements, of which the inspector is notified by phone. On Wednesdays, the territory is shared between the two ATMSs: one ATMS works a 13-hour shift and the other, an 8-hour shift. On Sundays, however, there is only one ATMS on duty and, in order to complete the rock patrol and the track inspection over the entire territory, the inspector works a 16-hour shift (usually between 0400 and 2000). Shift time does not include time required before and after work (such as commuting time, meals, etc.) which can add up to several additional hours.

1.11 Railway Culvert Inspection Program

Regular culvert inspections are performed to determine the condition of culverts and to identify work required to maintain the culverts in a safe operating condition.

Culvert inspection and maintenance practices are detailed in the Bridge Inspection Books (Form 920) and in CPR SPC No. 1 (Right-of-Way, Roadbed & Drainage) which states in part that:

> Culverts must be inspected as early as practicable in the spring of each year, and again in the fall before freeze-up. Any problems which cannot be rectified must be reported to the Roadmaster.

On 27 May 1997, CPR issued a new Culvert Inspection Policy extending the instructions contained in the Bridge Inspection Books (Form 920) and in CPR SPC No. 1. Highlights from the new policy are summarized below:

> CP Railway culverts shall be inspected in order to ensure the integrity of the structures, proper flow regimes are being maintained, note condition, note any change in condition, obtain information for structural or hydraulic capacity assessment of the culvert and/or determination of repair/rehabilitation requirements.
>
> Culverts less than or equal to 1 metre in span or diameter are to be inspected by track maintenance personnel, while those greater than 1 metre in span or diameter are to be inspected by Structures personnel. A SPC or revision to SPC No. 1 is being developed concerning the inspection of culverts less than or equal to 1 metre in diameter.
>
> Regular scheduled culvert inspections, shall be conducted at least annually and in the spring of each year.

The inspectors use the Record of Bridges and Culverts (Form 925) for recording conditions noted during the inspection of culverts. Form 925 is an extension of the Bridge Inspection Books (Form 920) and is a historical record which is expected to be kept current and available by each district.

Small culverts between Curzon (Mile 42.5) and Nelson (Mile 137.8) were inspected when indications of water flow irregularities or track subsidence started to appear. This practice was observed on other subdivisions and is used across the industry; for example, in January 1998, CN formalized SPC No. 4402 (Small Surface Drainage and Pipe Type Culverts) which states that:

> The inspection of small culverts is done as required when indications of distress start to appear at the culvert locations.

An examination of Form 925 for the Nelson Subdivision revealed that it was last updated between 1988 and 1991. A sample taken showed that 95 per cent of the entries were from 1988, 3 per cent from 1991 and 2 per cent were not dated. Similar recording practices were noted on other CPR subdivisions in Western Canada.

1.12 Transport Canada Inspection Audits

TC is responsible for administering and enforcing provisions of the *Railway Safety Act*, which has, as an underlying philosophy, the following roles for railway management and the regulator:

- railway management must be responsible and accountable for the safety of operations;
- the regulator must have the power to protect public and employee safety.

TC's approach to monitoring the safety of a railway's infrastructure is to review and audit the records of the railway's own compliance monitoring programs and then examine the end result by random site inspections. A method based on stratified sampling is used, with each region being divided into homogeneous groups and then subdivisions or sections of subdivisions selected from within the groups. For those selected subdivisions, inspection logbooks are reviewed and samples are taken to audit the inspection and maintenance programs for rail, track geometry, turnouts and bridges. Drainage and geotechnical programs were not formally included in the audit.

Non-compliance to the TSR related to the audited programs is noted on the TC form entitled "Track Inspection Defect Report" that is issued to the railways for corrective action. Any other non-compliance observed while riding the track is also noted on the form. When an abnormal rate of non-compliance is identified in a specific territory during regular inspections, a special inspection is carried out and the territory is then reinspected the following year.

The Nelson Subdivision is under the jurisdiction of the TC Pacific regional rail office located in Vancouver. A Railway Infrastructure Officer is responsible for monitoring the railway's infrastructure system. The officer was trained in the areas he was auditing and had attended an abbreviated version of the "Geotechnology for Railroaders" course in March 1998.

The Nelson Subdivision was inspected in September 1997, between Mile 0.0 and Mile 67.0; three drainage defects were noted, one at Mile 58.28 (water-carrying facility not maintained), one at Mile 50.33 (drainage facility not maintained), and one at Mile 44.65 (drainage facility not maintained).

1.13 Geotechnical Engineering Reports

A geotechnical engineering report was prepared by Dr. Stephen G. Evans (Geotechnical Engineer and Engineering Geologist for the Geological Survey of Canada) as an advisor to the Transportation Safety Board of Canada. The report concluded that:

> The derailment resulted from the failure of a 5 m high fill on a steep sidehill slope. Site observations and stability analysis indicate that the cause of the failure was the saturation of the fill. Seepage water discharging from the slope above the track, ponded in the upslope ditch and infiltrated the fill. Subsurface flow also contributed to water levels in the fill. During the month of May, the track was subjected to one of the most concentrated periods of rainfall since it was built.
>
> The materials in the fill were dominated by silty sand-silt materials that form the matrix of glacial and colluvial deposits in the vicinity of the site. These materials are glaciolacustrine in origin and their existence was a pre-requisite for the trackbed failure. Glaciolacustrine silts become significantly weakened when saturated. Consequently, controlling the flow of water and ensuring proper drainage is essential.

A geotechnical engineering report prepared by the CPR Geotechnical Group concluded that:

> The failure is believed to have been caused by higher than normal rainfall causing ponding in the up-slope ditch line which then infiltrated into the subgrade. The saturated fill failed when the hydraulic gradient became sufficiently high to cause failure of the upper mid-slope. If the culvert(s) capacity had been larger ponding in the ditch would have been limited and it is unlikely the failure would have occurred.
>
> The series of rainfalls experienced by the Creston - Goatfell area in late May was a rare occurrence, however, adequate ditch drainage through the strategic placement and adequate maintenance of culverts is critical to the performance of the rail grade.

1.14 Hydraulic Analysis

The hydraulic analysis presented in the CPR geotechnical report indicated that additional culverts would be required if the present CPR design criteria are applied; the inlet flow depth cannot exceed 2/3 of the culvert diameter. However, the diameter of the existing culvert would be considered adequate if American Railroad Engineering and Maintenance-of-Way Association (AREMA) standards are used. The analysis was based on a design discharge flow of 0.51 m^3/s that corresponds to the 100-year return period rainfall.

A TSB calculation using the same discharge flow showed that the inlet flow depth in the culvert[5] located immediately near the depression would have surpassed the culvert crest, resulting in over 30 inches of water ponding in the ditch.

1.15 Previous TSB Recommendations

Materials susceptible to saturation, such as glaciolacustrine silts, were encountered recently in other occurrences: Orient Bay, Ontario (TSB report No. R94W0101), Pointe-au Baril, Ontario (TSB report No. R97T0097), and Conrad, British Columbia (TSB report No. R97V0063). Subsequent to the Conrad occurrence, the Board issued the following Interim Railway Safety Recommendations to address risks associated with these types of materials:

> The Department of Transport, in collaboration with Canadian National, Canadian Pacific Limited, and the British Columbia highway authority:
> a) identify locations where railway or adjacent highway roadbeds were constructed of fill laid on silts or other soil material;
> b) for those locations identified as per above, assess the adequacy of existing drainage for the spring run-off and determine if the roadbed foundations are susceptible to water saturation; and
> c) where applicable, implement a monitoring program to detect roadbed subgrade instability as a result of water saturation.
>
> (R97-01, issued April 1997)

> The Department of Transport, in collaboration with the Railway Association of Canada:
> a) evaluate the effectiveness of current track continuity warning systems vis-à-vis roadbed failures;
> b) evaluate alternative methods for confirming the integrity of the roadbed during high risk periods; and
> c) sponsor research to develop more reliable technologies for monitoring the integrity of both the track and the roadbed.
>
> (R97-02, issued April 1997)

In response to Recommendation R97-01, TC indicated that several actions had been taken, including aerial and ground surveys, the identification of sites with the potential for similar problems and the installation of a slump/washout detector at Conrad. With respect to Recommendation R97-02, TC held meetings with the Railway Association of Canada, CN and CPR regarding the current track continuity warning systems. Existing technologies were

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[5] This calculation assumes that the culvert inlet was unrestricted.

examined and their limitations were recognized; the response indicated that there are plans to test the different technologies. TC did not state at that time that it would specifically sponsor the research suggested by the recommendation.[6]

[6] See subsection 4.1 for updated information.

2.0 Analysis

2.1 Introduction

The Creston failure again illustrated the potential instability of silty fills, dating from the early days of the railway network, when subject to saturation.

While the majority of subgrades perform adequately, their stability is influenced by the type of materials, the slope of the terrain and the drainage. This was recognized in Interim Railway Safety Recommendation R97-01, issued in April 1997, subsequent to the Conrad derailment, and through the actions taken by the railway industry along the mainline routes. Programs aimed at reducing the risks associated with slope instability include the following elements: the identification of locations where the materials are sensitive to saturation, the assessment of drainage, and the implementation of a monitoring program.

As a result of the record rainfall, the subgrade fill material beneath the track became saturated and weakened; once its integrity could no longer be maintained, it catastrophically failed before the train reached Mile 59.1. Site observations, the geotechnical reports and the TSB hydraulic calculations concurred that water was ponding in the ditches and contributed to the saturation of the subgrade. Had an additional inspection been carried out before the derailment, the ponding would have been detected; however, without training on soil stability and proper identification of the susceptibility of the site to water saturation, the significance of the ponding would not have been fully appreciated. The analysis will focus on the shortcomings of the inspection and slope stability programs in place on the Nelson Subdivision at the time of the derailment.

2.2 Site Identification

Although the Nelson Subdivision is located in mountainous terrain susceptible to both rock slides and soil slope instability, only the rock slope stability program was in place. The soil slope stability program initiated by CPR was concentrated on mainline routes and had not yet reached low-density lines. As a result, sites susceptible to slope instability had not been identified on the Nelson Subdivision. Since soil instability is site-specific, it is crucial to properly identify the areas of concern and focus monitoring program resources on these sites. Without this necessary step, efforts to mitigate risks associated with soil instability will be ineffective.

2.3 Drainage

Although CPR has a clear policy on culverts and drainage issues, this policy is not implemented in the field.

Normally, excess water flow is channelled through culverts along the track; however, as observed in the area of the derailment, culverts were not functioning as would be expected. It was noted that the flow of water through small culverts was restricted, silt deposits were accumulating and water was ponding in the bottom of the surface ditch along the track. Annual programs are not carried out systematically and records are not being updated for the small culverts under the responsibility of track forces. There is no "hands and knees" inspection to verify the integrity and the hydraulic conditions of the culverts. Essentially, while inspecting track by Hi-rail, inspectors will observe track subsidence and high water back-up.

Although ditches and small culverts are an integral part of the drainage system, their role is underestimated. The malfunction of small culverts is perceived to cause water ponding but not high water back-up and washouts. The result is that action is only taken when signs of distress are visible. This is occurring even though small culverts by their very nature are more susceptible to getting plugged by debris or vegetation and, therefore, should require more attention. This practice is widespread across the industry and has been formalized at CN.

While this practice may be acceptable in the great majority of the locations across the country, it may not be appropriate in all locations. High water back-up might constitute an adequate advance warning on a flat territory where slopes are relatively stable; however, in areas susceptible to slope movement, a sudden subgrade failure might be triggered by relatively shallow ponding water.

2.4 Monitoring Programs

2.4.1 Training

Among the two ATMSs and the two relieving foremen who were performing inspections, only one had formal rock slope stability training and none had received soil slope stability training.

While the CPR slope stability programs are based upon annual inspections by its Geotechnical Group and consultants, the programs rely upon information provided by local inspectors who, by their continual exposure to the surrounding territory, are best able to assess slope performance. The inspectors not only need to recognize that there has been a change, but they also need to have a basic understanding of the significance of the observed change, so that it can be appropriately reported and acted upon.

Untrained inspectors can determine whether rocks have fouled the track or if track subsidence or high water back-up exist and, if necessary, take action to protect the advancing train. However, they will lack the knowledge and skills to properly assess rock slope and soil performance compromising the slope stability programs and leaving unsafe conditions undetected.

2.4.2 Adequacy of Track Inspections

Track inspection requires performing a large number of separate but concurrent visual inspection tasks (rail, rail joints, anchors, ties, tie plates, spikes, ballast, turnouts, crossings, signal equipment, drainage, cuts and embankments, fencing, and clearances). While turnouts and crossings are inspected separately, the remaining inspection tasks are carried out simultaneously while travelling by Hi-rail at 20 mph. When people are required to do more than one task at the same time, performance on at least one of the tasks often declines. It is generally agreed that humans have a limited capacity to process information, and when several tasks are performed at the same time, that capacity can be exceeded. People can keep track of between five and nine items of information at one time. However, if a number of concurrent tasks make use of only one sense, like vision in the case of track inspectors, then this number is further reduced.

Another factor which can decrease the available cognitive capacity of track inspectors is the number of hours on duty. On Sunday, when there is no sharing of duties, the inspector is on duty for up to 16 hours. If other activities required before work, such as commuting and meals, are included, an inspector could have been awake in excess of 18 hours towards the end of his/her inspection tasks. Although the rate of performance degradation on cognitive and vigilance tasks has not been well documented for periods of less than 18 hours without sleep, researchers at the Defence and Civil Institute of Environmental Medicine found that, after 18 hours without sleep, individuals showed a 30 per cent decrement in performance.

Furthermore, track inspections are, on average, carried out between the hours of 0400 and 2000. While not germane to this derailment, this means that some track inspections are carried out during periods of darkness during winter months.

Each of the above factors (concurrent tasks, long working hours and darkness) on their own can reduce the ability of inspectors to carry out their duties. The situation is aggravated when the factors are combined making it difficult for track inspectors to ensure that a complete and adequate inspection is carried out for the safe passage of trains.

2.4.3 Additional Inspections

Despite the fact that rainfall is only one of a host of variables affecting the stability of slopes, the record precipitation during the week preceding the derailment should have warranted an additional inspection or additional inspections. No additional inspection was performed even though the employees stated that they were not restricted in any way from carrying out additional inspections when required. Without quantifiable criteria on the severity or intensity of rainfall, employees were unable to determine if an additional inspection was required to ensure that an unsafe condition was created by the heavy rain.

While both CPR and TC call for additional inspections during or subsequent to unusual weather conditions, neither clearly quantify the criteria to be used to assess what constitutes an unusual weather condition. For instance, there is no clear criterion defining "heavy rain" in SPC No. 32 or a "severe storm" in the TSR.

Furthermore, there is no formal weather monitoring system in place. The decision to undertake additional inspections is left to the discretion of the local TMS or ATMS. The local employees rely on their own assessment of weather conditions over their entire territory. Their awareness of weather conditions across the territory might be limited to the information they are able to gather personally in their immediate surrounding. A heavy storm happening in the middle of the night or when the local employees are temporarily away from their territory might not be noticed, with the potential of an unsafe condition remaining undetected. Advance warning of adverse conditions will provide a global picture of the weather forecast across the territory and place the TMS in a heightened state of alertness and readiness to respond. The need for such a system is evident as some TMSs have developed their own system and other railways have implemented comprehensive weather monitoring systems.

Given the importance of water on slope stability, an additional inspection after unusual weather conditions is paramount for the success of the soil slope stability program. This cannot be achieved without a weather warning system in place and without clear criteria of when to launch the additional inspections.

2.5 Advance Warning of Subgrade Failures

The configuration of the track east of the depression and the limited daylight would have impaired the crew's ability to prepare for the impending hazard. As this and other accidents of this type have demonstrated (TSB report Nos. R97V0063 and R97T0097), subgrade failures do not necessarily occur under load and can happen before the arrival of a train. This derailment reinforces the pertinence of Interim Railway Safety Recommendation R97-02 and the need for methods to alert train crews of an impassable track due to a subgrade failure.

3.0 Conclusions

3.1 Findings

1. The manner of train operation played no role in the derailment.

2. Due to the track configuration, the time of day (night-time), and the absence of an advance warning system for subgrade failures, the train crew members were unaware of the subgrade failure ahead of them.

3. The subgrade fill material, primarily composed of glaciolacustrine silts, became saturated and catastrophically failed before the arrival of the train.

4. Glaciolacustrine silts weaken significantly when saturated. Consequently, controlling the flow of water and ensuring proper drainage is essential on sites where they are present.

5. Record rainfall fell in the month of May and in the days preceding the subgrade failure. On Wednesday, 27 May 1998, the 100-year return period rainfall was exceeded.

6. Water had been ponding in the ditches and contributed to the saturation of the subgrade.

7. The assessment of ditches and small culverts across the industry is reactive; action is taken only when signs of distress are visible.

8. While performing inspections by Hi-rail, track inspectors use track subsidence and high water back-up as signs of drainage problems; however, a subgrade failure can be triggered by soil saturation caused by shallow ponding water in areas susceptible to slope instability.

9. Although the Nelson Subdivision is located in mountainous terrain, the CPR soil slope stability program was not in place in this territory; therefore, sites susceptible to soil slope instability were not identified.

10. Among the personnel performing inspection duties, only one had received rock slope stability training and none was trained in soil slope stability. The use of untrained personnel can compromise slope stability programs.

11. Extended hours of duty, coupled with the large number of tasks and conditions surrounding track inspection, can have a detrimental effect on the adequacy of the inspections.

12. Although employees stated that they were not restricted in any way from carrying out additional inspections when required, an additional inspection was not performed subsequent to the record rainfall on Wednesday, 27 May 1998.

13. There is no weather warning system in place and no clear criteria in the TSR and in the railways' SPCs to help determine when additional inspections are required.

14. Had an additional inspection been carried out before the derailment, the water ponding in the ditches would have been detected; however, without training on soil stability and proper identification of the susceptibility of the site to water saturation, the implications of water ponding would likely not have been fully appreciated.

15. TC monitoring programs were not geared to drainage and slope stability issues.

3.2 Cause

The track failed due to saturation and failure of the subgrade fill. Contributing factors were the record rainfall, the performance of the drainage system, the steep sidehill slope, and the high susceptibility of the subgrade fill material to water changes.

4.0 Safety Action

4.1 Action Taken

CPR has introduced a program to address the issue of fatigue in the Engineering Services Department of the BC District. As part of this initiative, an employee awareness program called *Lifestyle Employee Awareness Program* (LEAP) has been implemented as a joint labour/management project focussed on track program crews. Several measures affecting work scheduling, crew lodging, transportation and commuting were included in this program. LEAP was recently redesigned and renamed *Shifting to Wellness*. This program is now offered to other service areas and will become part of the basic training curriculum for all operating employees.

All three track maintenance supervisors on the Nelson Subdivision have now completed the rock and soil slope stability training courses.

A new culvert inspection policy was issued in June 1999. It requires that all culvert inspections be carried out annually by structures personnel.

CPR contracted the services of World Weather Watch for a warning system. Such a system provides railway employees with a detailed, accurate weather forecast referenced to track mileage and station. It also provides severe weather notification and flood warnings.

The TC track monitoring program was modified in 1998. TC railway safety inspectors were instructed to focus on drainage issues and review railway maintenance practices in territories susceptible to slope instability. In addition, TC's regional office in Vancouver hired a professional engineer, in the summer of 1999, to carry out inspections and audits for the railway rock and soil slope stability programs.

TC is currently negotiating an agreement with the Geological Survey of Canada and other sponsors for a complementary research project on landslide hazard risk mitigation. The results of the research will provide analytical tools for characterizing landslide hazards and assist the railway companies in identifying potential unstable areas.

TC's Railway Safety Directorate is also co-sponsoring a research project to develop reliable techniques for monitoring railway track for rock or soil slides and alert train crews of an impassable track. A guided radar system, based on the detection of disturbances caused by these hazards in the electromagnetic field around sensor cables laid along the track, is under study. A pre-production prototype is being tested on the CPR mainline near Golden, British Columbia. A second installation, located on CN tracks at Stoney Plains, was set to verify performance on concrete ties. A technical report on the project is expected to be available soon.

4.2 Safety Concern

The Board recognizes the concerted effort by the railway and the regulatory body to address the issues related to soil and rock slope stability. Research projects such as the guided radar system and the landslide hazard risk mitigation are undoubtedly positive steps towards the reduction of risks associated with slope stability. The implementation by the railways of a comprehensive weather monitoring system will also provide an advance warning of adverse weather conditions and allow TMSs to be in a heightened state of alertness and readiness to carry out additional inspections.

While both CPR and TC call for additional inspections during or subsequent to adverse or unusual weather conditions, neither clearly quantify the criteria to be used to assess what constitutes an unusual weather condition. The Board realizes that the weather is only one of a host of variables affecting the stability of slopes and that its influence is not reliably predictable. Furthermore, it is difficult and not practicable to include all the variables and establish threshold values of when to launch additional inspections after unusual weather conditions. However, given the impact of water on slope stability, the Board is concerned that, without clear guidelines, local employees will rely on their sole judgement to assess the severity or intensity of rainfall and might not be able to determine consistently when to respond, to ensure that unsafe conditions are not left undetected.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Jonathan Seymour, Charles Simpson, W.A. Tadros and Henry Wright, authorized the release of this report on 13 January 2000.

Appendix A - Glossary

ATMS	Assistant Track Maintenance Supervisor
BC	British Columbia
cm	centimetre(s)
CN	Canadian National
CPR	Canadian Pacific Railway
KVR	Kootenay Valley Railway
LEAP	*Lifestyle Employee Awareness Program*
m	metre(s)
m^3	cubic metre(s)
m^3/s	cubic metre(s) per second
mm	millimetre(s)
mph	mile(s) per hour
PST	Pacific standard time
SPC	Standard Practice Circular
TC	Transport Canada
TMS	Track Maintenance Supervisor
TSB	Transportation Safety Board of Canada
TSR	Track Safety Rules
UTC	Coordinated Universal Time