Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

RAIL TRANSPORTATION SAFETY INVESTIGATION REPORT R22C0065

MAIN-TRACK DERAILMENT

Canadian Pacific Railway Company
Train 301-222
Mile 97.4, Brooks Subdivision
Near Bassano, Alberta
13 July 2022

Canada

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Transportation Safety Board of Canada
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741; 1-800-387-3557
www.tsb.gc.ca
communications@tsb.gc.ca

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Summary

On 13 July 2022, at about 1618 Mountain Daylight Time, Canadian Pacific Railway Company train 301-222 was travelling westward at 44 mph on the Brooks Subdivision when 41 hopper cars loaded with grain derailed at Mile 97.4, near Bassano, Alberta. Thirty-nine of the derailed cars were breached and spilled grain on the ground in varying amounts. There were no dangerous goods involved, and no fire was reported. No one was injured.

1.0 FACTUAL INFORMATION

On 13 July 2022, Canadian Pacific Railway Company (Canadian Pacific or CP)[1] train 301-222 departed Medicine Hat, Alberta, destined for Vancouver, British Columbia. The train was a unit train[2] hauling 203 hopper cars loaded with grain; it measured 11 758 feet and weighed 29 021 tons. The train was powered by 5 locomotives: 2 at the head end, 2 mid-train (positions 106 and 107), and 1 at the tail end (position 208). The mid-train and tail-end locomotives were controlled from the lead locomotive by means of distributed power remote control technology.[3]

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[1] On 14 April 2023, Canadian Pacific Railway Company (CP) and Kansas City Southern (KCS) combined into a single railway company doing business as CPKC. As the occurrence took place before the transition date, the acronym CP will be used throughout the report.

[2] A unit train is a train carrying a single commodity in cars of similar type, length, and weight.

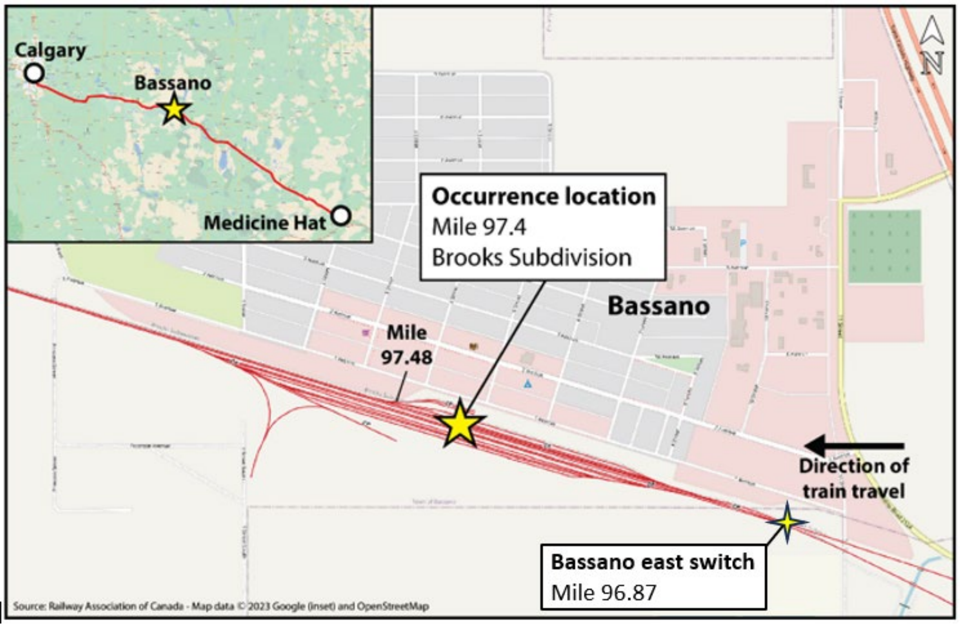
[3] When a remotely controlled locomotive receives a distributed power radio message from the lead locomotive, it responds by executing the train-handling commands it receives.

The operating crew consisted of a locomotive engineer and a conductor; both crew members met established rest and fitness requirements, were qualified for their respective positions, and were familiar with the territory.

1.1 The occurrence

At about 1618 Mountain Daylight Time, while the train was travelling westward at 44 mph on the Brooks Subdivision on an average 0.34% ascending grade, a train-initiated emergency brake application occurred. Once the train stopped, the crew performed an inspection and determined that 41 cars (positions 116 to 132 and 135 to 158) had derailed at Mile 97.4, near Bassano, Alberta (Figure 1). There were no dangerous goods involved, and no fire was reported. No one was injured.

Figure 1. Map of the occurrence location, with inset showing the location of Bassano, Alberta (Source of main image: Railway Association of Canada, *Canadian Railway Atlas*, with TSB annotations. Source of inset image: Google Earth, with TSB annotations)



Source: Railway Association of Canada - Map data © 2023 Google (inset) and OpenStreetMap

1.2 Site examination

The 1st car to derail (SOO 115291, the 9th car behind the 2 mid-train remote locomotives, in position 116) was upright and remained coupled to the head-end portion of the train. There was a gap of approximately 1500 feet to the next car (SOO 115130, in position 117), which was on its side to the north of the track and separated from the other cars (Figure 2). In the vicinity of this car, the south rail was upright but kinked; the north rail was rolled to the north.

Figure 2. View from the north side of the main track, looking west, showing the second derailed car rolled on its side and, further in the distance, the first derailed car, which remained upright and coupled to the head end of the train (Source: Canadian Pacific)

The next 7 derailed cars (positions 118 to 124) were also derailed to the north, stretched out beside the track, and had come to rest on their sides. The remaining derailed cars were in 3 distinct pile-ups (Figure 3): the 1st pile-up consisted of 8 cars (positions 125 to 132), the next pile-up consisted of 16 cars (positions 135 to 150), and the last pile-up consisted of 4 cars (positions 155 to 158). The intervening cars (positions 151 to 154) remained coupled to each other, upright or leaning, and aligned along the right-of-way. The cars in positions 133 and 134 did not derail.

In total, 41 cars had derailed, 39 of which were breached and lost product in varying amounts.

Figure 3. View from the south side of the main track, looking east, showing several pile-ups of derailed cars (Source: Canadian Pacific)

Some of the cars in the 2nd pile-up had come to rest against a cut of cars in the adjacent yard track and were damaged.

The main and siding track in the area of the derailment were destroyed. The nearest adjacent yard track also sustained damage. Among the wreckage, there were wooden ties with clips and screws designed for switch locations.

In addition, a fibre-optic trunk line, which runs parallel to the track, was damaged in the derailment. Data transmission service provided by this line was interrupted until the line's owner made the necessary repairs.

In total, derailment repairs included 3450 feet of main track, 1440 feet of siding, and 1000 feet of adjacent yard track between Mile 97.3 and Mile 97.9 of the Brooks Subdivision.

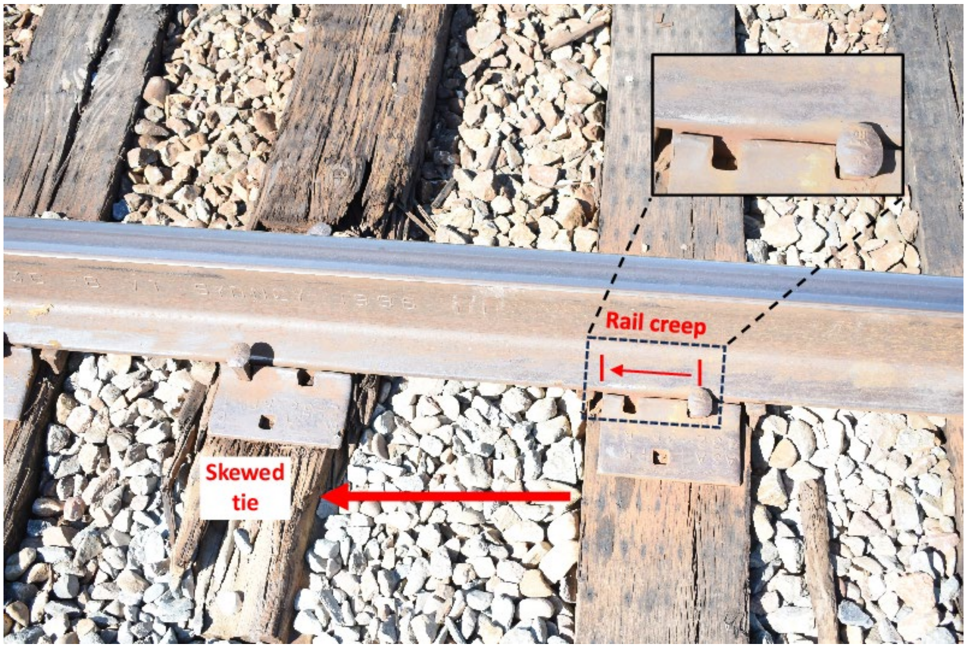
1.2.1 Condition of the track in the vicinity of the derailment

TSB investigators visually examined about 10 miles of undamaged track east of the derailment area. It was determined that the east-end main-track switch at Bassano had been replaced in September 2021. The rail, ties, tie plates, elastic fastenings, anchors, and ballast in the vicinity of the switch were in excellent condition. However, the track further to the east, and to the west between the newly installed switch and the east end of the section of track destroyed by the derailment, showed signs of deterioration (Figure 4), including:

- contaminated and worn crushed rock ballast, with some rounded stones and degraded ballast pieces;
- skewed, worn, and plate-cut ties;

- base rail movement (rail creep)[4] through anchors and spikes;
- lifted spikes; and
- missing or loose anchoring.

Figure 4. Condition of the main track just east of the derailment, showing the south rail with lifted spikes, worn ties, a skewed tie, and rail creep (Source: TSB)



At the time of the TSB's site examination, CP personnel were in the process of replacing missing anchors, repositioning anchors that might have moved, and also box anchoring[5] every tie between the Bassano east switch and the main track that had been reconstructed post-occurrence.

1.2.2 Examination of the first derailed car

The 1st derailed car, SOO 115291, was moved to an adjacent track for a detailed inspection and truck teardown. The inspection determined that the truck components were within operating specifications. There was no wear typically associated with excessive truck hunting.[6] The car had not triggered any recent alerts or alarms from wayside truck hunting detectors.

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[4] Rail creep is the gradual longitudinal movement of the rail and is induced by variations in temperature (thermal stress), train traffic (predominantly unidirectional loaded traffic), or both. When rail creep is traffic-induced, the rails move in the direction of the traffic.

[5] Box anchoring means securing the rails with 4 anchors per tie, which is considered one of the most secure ways to anchor and prevent longitudinal movement of the rail.

[6] Truck hunting is the lateral oscillation of a wheel set from rail to rail due to the dynamic response of the rail car truck as it travels along the track. Truck hunting is associated with lightly loaded or empty cars and speeds of about 50 mph or greater.

1.3 Weather information

On the day of the occurrence, it was sunny and clear, with a daytime high temperature of 25.4 °C.

In the days before the occurrence, there was a sudden rise in daytime temperature in the Bassano area, from 14.9 °C on 04 July to 23.3 °C the following day. After this rise and until the day of the derailment, the daytime temperatures remained high, ranging from 21.7 °C to 31.6 °C, while the nighttime temperatures dropped as low as 6.7 °C (Table 1).

Table 1. Maximum and minimum temperatures from 04 to 13 July 2022 recorded for the Bassano weather station (Data source: Environment and Climate Change Canada)[7]

Date	Time of maximum temperature recording	Daytime maximum temperature		Nighttime minimum temperature	
		(°C)	(°F)	(°C)	(°F)
2022-07-13	1700	25.9	78.6	9.2	48.5
2022-07-12	1600	31.6	88.9	6.7	44.1
2022-07-11	1700	26.2	79.2	9.1	48.4
2022-07-10	1900	24.8	76.6	11.0	51.8
2022-07-09	1800	26.2	79.2	10.2	50.4
2022-07-08	1800	28.3	82.9	12.9	55.2
2022-07-07	1600	25.8	78.4	12.3	54.1
2022-07-06	1400	21.7	71.1	10.0	50.0
2022-07-05	1800	23.3	73.9	11.0	51.8
2022-07-04	1900	14.9	58.8	12.3	54.1

1.4 Recorded information

1.4.1 Forward-facing camera

The lead locomotive and the trailing mid-train locomotive were each equipped with a forward-facing camera. A review of the recordings determined that the lead locomotive passed over Mile 97.41, the location where an urgent track alignment defect had been recorded on 07 July 2022 (about a week before the derailment), without any abnormal side-to-side movement or observable track misalignment. However, when the mid-train locomotives passed over the same location, there was a noticeable side-to-side sway in the video recording.

1.4.2 Locomotive event recorder

The lead locomotive was equipped with a locomotive event recorder. A review of the recorder's data determined that, at the time of the occurrence, the train was operating with

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[7] Past weather and climate historical data (hourly historic data for each of the relevant days), on Government of Canada website, at https://climate.weather.gc.ca/historical_data/search_historic_data_e.html (last accessed on 17 December 2024)

Trip Optimizer engaged.[8] The locomotives had been in throttle notch 8 for about 3.5 minutes when the train-initiated emergency brake application occurred; no train handling anomalies were noted during this time.

1.5 Subdivision information

The Brooks Subdivision extends from Medicine Hat (Mile 0.0) to Calgary, Alberta (Mile 175.8). Train movements on the subdivision are governed by the centralized traffic control system, as authorized by the *Canadian Rail Operating Rules* and dispatched by a CP rail traffic controller located in Calgary.

1.6 Particulars of the track

The track at Mile 97.4 of the Brooks Subdivision is designated as Class 4 track under the *Rules Respecting Track Safety*, also known as the Track Safety Rules (TSR). For class 4 track, the TSR permit a maximum authorized speed of 60 mph for freight trains. In the area where the derailment occurred, the authorized maximum operating track speed was 55 mph, as reflected in the timetable for the Brooks Subdivision. The subdivision runs through prairie terrain, which is known for seasonal temperature extremes and daily temperature variance. In the prairies, "periods of above- and below-average conditions are typical and tend to be cyclical."[9]

In the area of the derailment, the tangent single main track structure consisted of 136-pound continuous welded rail (CWR) manufactured by Sydney Steel Corporation and installed in 1996. The rails were laid on hardwood ties, secured on 14-inch double-shouldered tie plates, and fastened with 2 to 3 spikes per plate.

They were box-anchored every other tie, in accordance with CP's *Red Book of Track & Structures Requirements* (the Red Book).[10] The ballast consisted of crushed rock with full cribs and 12-inch shoulders; it was worn, with some rounded stones and degraded ballast pieces.

About 1.5 miles east of the derailment area, starting at Mile 96.0 and extending to Mile 103.6, the track ascended a moderate grade varying between 0.2% and 0.7% (average grade of 0.34%) with a short segment of 0.4% descending grade (a sag) from Mile 97.0 to Mile 97.3. There was a shallow (1.46° to 1.80°) left-hand curve from Mile 96.7 to Mile 97.0.

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[8] Trip Optimizer is an energy management system that minimizes fuel usage by automatically controlling the locomotive throttle and dynamic brake functions. It is similar to a cruise control system on a car.

[9] D. Actor and A. Bedard-Haughn, "Prairie," *The Canadian Encyclopedia*, at https://www.thecanadianencyclopedia.ca/en/article/prairie (last accessed 17 December 2024).

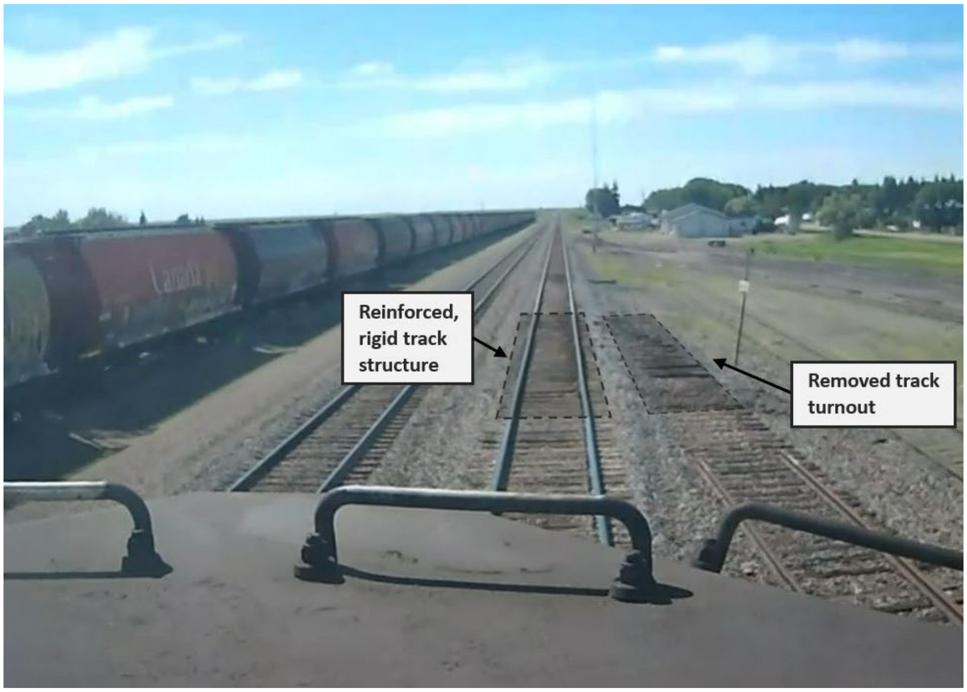
[10] Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 18 May 2022), Appendix 9: Anchoring Patterns Bolted & CWR, p. 158.

1.6.1 Partially removed track turnout

At Mile 97.48, a track turnout (Figure 5), which previously connected the Brooks Subdivision to the Irricana Subdivision, had been decommissioned. After Irricana Subdivision operations were discontinued, a short portion of the track remained in service and was used for rail car set-outs and storage of equipment. In 2020, the remaining portion of the track was disconnected; the switch stand, switch points, closure rails, and frog were removed. However, the long switch ties were left in place, and the rails were still box-anchored at every tie for 200 feet in each direction and rigidly secured.

Although the track turnout at this location had been removed, the main-track structure that had previously been reinforced, per turnout design standards, remained as a rigid and solidly fixed location.

Figure 5. View of the location where the track turnout had been removed at Mile 97.48, as seen from the train's lead locomotive (Source: Canadian Pacific, with TSB annotations)



1.7 Track inspections

For federally regulated track, the regulatory requirements for track maintenance and inspections are set out in the TSR, which are the minimum safety requirements.

According to the TSR, the minimum frequency for visual inspections of Class 4 CWR track with annual traffic greater than 15 million gross tons (MGT)[11] is twice weekly.[12]

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[11] In 2022, annual traffic on the Brooks Subdivision was 68.9 million gross tons. Historic data on traffic volume and density since 2015 is provided in section 1.12.

[12] *Rules Respecting Track Safety* (approved by Transport Canada 02 February 2021, effective 01 February 2022), part II, section 2.4: Visual Track Inspections, pp. 34–35.

The TSR also require that Class 4 CWR track with annual traffic between 35 and 80 MGT receive

- a rail flaw inspection 4 times annually at a minimum,[13] and
- an electronic geometry car inspection by a heavy geometry inspection vehicle (HGIV) 3 times annually at a minimum.[14]

1.7.1 Visual inspections

Visual inspections are usually conducted by hi-rail vehicle. When a track condition of concern is identified, the operator may get out of the vehicle to take a closer look and, if necessary, make repairs or implement track protection until repairs can be made.

From 13 April to 13 July 2022, CP track inspectors conducted 33 visual inspections of the Brooks Subdivision between Mile 95.0 and Mile 105.0. Seventy-nine percent (79%) of the inspections reported no defects. Where defects were identified and repaired,

- 75% (30 to 40) were for missing or loose bolts, and
- 5% were for broken joint bars.

1.7.2 Rail flaw detection inspections

Rail flaw detection (RFD) inspections identify internal rail defects through the use of non-destructive ultrasonic technology.

RFD inspections were conducted monthly in 2022, with the most recent test before the occurrence conducted on 29 June. No defects were detected in the area where the derailment occurred.

1.7.3 Track geometry inspections

Track geometry inspections measure and evaluate important track conditions such as alignment, surface, cross level, gauge, and curvature.

1.7.3.1 Track geometry inspection technologies

Track geometry inspections are conducted using either HGIVs or light geometry inspection vehicles.

There are various types of HGIVs, including track evaluation cars (TECs) and boxcars equipped with an autonomous track geometry measurement system (ATGMS); both can measure dynamic rail movements under loaded conditions.

TECs are occupied vehicles. They are sometimes equipped with a gauge restraint measuring system (GRMS), which applies lateral loads to test the lateral strength of the track. The

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[13] Ibid., section 5: Track – Rail Flaw Inspections, pp. 42–44.

[14] Ibid., section 4: Track – Electronic Geometry Inspections, pp. 39–41.

GRMS can simulate a gauge-widening force of 16 000 pounds acting on the gauge face of the rails.

ATGMS are unoccupied boxcars that use a non-contact, laser-based optical alignment inspection system to test the track under a loaded condition. The system generates a report, and an email notification is sent to CP track maintenance supervisors. It is common practice for field personnel to confirm the presence of any identified urgent defect by a follow-up visual inspection. CP's Red Book does not provide procedures for verifying defects identified by ATGMS inspection.

When using a light geometry inspection vehicle, the vertical wheel load applied to the track is limited to the weight of the vehicle; therefore, the measurements obtained do not account for dynamic rail movements that occur under train loading conditions. The TSR therefore require that measurements be corrected accordingly:

> When unloaded track is measured to determine compliance with requirements of these Rules, the amount of rail movement which occurs while the track is loaded must be added to the measurements of the unloaded track.[15]

1.7.3.2 Classification of geometry defects

CP categorizes track geometry defects as priority, near-urgent, or urgent:[16]

- A priority defect has not yet reached a condemnable limit per the TSR but is trending close. Priority defects must be corrected as soon as possible to ensure that they do not deteriorate, becoming urgent defects.
- A near-urgent defect is a priority defect that is within ⅛ inch of becoming urgent.
- An urgent defect exceeds the TSR's condemnable limit and requires immediate correction, with a mandatory track-speed slow order (unless corrected before the passage of the next train).

CP does not have a near-urgent or priority category for narrow-gauge defects. Narrow gauge is reported only as an urgent defect—i.e., when the measured gauge is less than or equal to 56 inches.

1.7.3.3 Geometry inspection results

CP provided track geometry inspection records for the Brooks Subdivision from 24 June 2021 to 13 July 2022. A review of the data revealed the following:

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[15] Ibid., part I, section 8.1: Measuring Track Not Under Load, p. 9.

[16] Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 18 May 2022), and *Track Evaluation Cars: Guidelines for Defects & Reports* (2014).

- Inspections conducted by ATGMS through this period indicated the presence of 2 AL/62 alignment defects[17] at Mile 97.41, within 30 feet of each other. The defects were categorized as priority defects until the 07 July 2022 inspection, at which point they had progressed to urgent defects.
- Inspections conducted using ATGMS also found a high number of urgent narrow-gauge defects. For instance, the 07 July 2022 inspection, covering about 139.66 miles from Mile 0.0 to Mile 144.3, found 59 urgent narrow-gauge defects, 2 of which were located in the area where the train derailed (one at Mile 96.50 and the other at Mile 96.81). Narrow-gauge defects can be an indication of insufficient track securement and/or excessive compressive stress.
- Inspections conducted by TEC equipped with GRMS, in contrast, found predominantly urgent wide-gauge defects. For instance, the 04 July 2022 inspection (the last GRMS inspection before the derailment) found 22 urgent G WIDE defects.[18] These defects were measured in the same section of track where the ATGMS had found predominantly narrow-gauge defects.
- The number of urgent defects found by the ATGMS varied significantly, depending on the time of day when the inspection was conducted. For instance, the inspections on 18 April and 09 June 2022 were conducted in the cooler hours of the day, the first at 0005 and the other at 2138; these inspections found 6 and 14 urgent defects, respectively. In contrast, the inspections on 11 May and 07 July 2022 were conducted in the hotter hours, the first at 1150 and the other at 1415, and found a significantly higher number of defects (46 and 62, respectively).

In the ATGMS inspection reports, several defects were amended. When defects reported by ATGMS are verified through manual inspection, if a defect's measurement varies from the reported measurement, the record is amended to reflect the measurement obtained through the manual inspection.

1.7.3.4 Canadian Pacific guidance on measuring and correcting narrow gauge defects

The CP *Track Evaluation Cars Guidelines for Defects and Reports* ("TEC Book") describes 24 defects that can be identified by TEC, as well as 4 that can be identified by GRMS. It includes guidance that TEC measurements are taken under load and that the value detected may be greater than unloaded measurements taken by track workers.[19]

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[17] AL/62 is the measurement, in inches, of the alignment at the midpoint of a 62-foot line. According to *the Rules Respecting Track Safety*, on Class 4 tangent track, the deviation of the mid-offset from a 62-foot line may not be more than 1½ inches. [Source: *Rules Respecting Track Safety* (approved by Transport Canada 02 February 2021, effective 01 February 2022), Part II, section C, item 3: Track Alignment, p. 13].

[18] "G WIDE" stands for "gauge-widening ratio channel" and is a measure of how well the track can hold gauge. A G WIDE defect is considered urgent if the track gauge is more than 57.5 inches wide (1 inch over standard gauge) under GRMS loading and the movement of the track under loading is greater than 1 inch.

[19] Canadian Pacific, *Track Evaluation Cars Guideline for Track Defects & Reports*, 02 September 2014, p. 20

With regards to narrow gauge defects, guidance is provided for adjusting unloaded measurements taken with a measuring tape. The value of the adjustment varies depending on whether the track is showing symptoms of wear (Table 2). Listed symptoms include tie plates canted inwards, clusters of bad ties, skewed ties, and broken plates.

Table 2. Guidance on adjusting unloaded measurements of narrow gauge defects to account for track behaviour under load

	Measurement adjustment for track without wear symptoms (inches)	Measurement adjustment for track with wear symptoms (inches)
Main line – Outside the joint	$^{1}/_{16}$	$^{3}/_{16}$
Main line – In the joint area	⅛	$^{5}/_{16}$
Branch line – Outside the joint	⅛	¼
Branch line – In the joint area	$^{3}/_{16}$	$^{5}/_{16}$

In this occurrence, inspections found 2 narrow gauge defects near the area where the derailment occurred (on a mainline, outside a joint). The track in the area was symptomatic, and therefore an additional $^{3}/_{16}$ inches should have been added to unloaded measurements. There is no record that such adjustments were made to unloaded measurements to account for loaded conditions.

1.7.4 Regulatory inspections

Transport Canada (TC) is responsible for setting safety standards for railway operations and overseeing the safety of such operations. As part of the Department's oversight activities, TC railway safety inspectors gather information through records compliance and track inspections to determine whether a railway is managing its track safely. A typical track inspection consists of a review of railway practices, a visual inspection of the track and automated track geometry testing using a light geometry inspection vehicle. These inspections enable TC to evaluate the effectiveness and adequacy of the railway inspection programs and to determine compliance with the TSR.

TC inspected the track on the Brooks Subdivision once in 2021 and once in 2022.

On 10 August 2021, TC inspected the track from Mile 56.30 to 92.62 (36.32 miles). The inspection did not include the section of track involved in this occurrence. Following this inspection, TC issued a letter of non-compliance on 18 August 2021. The letter listed 4 non-compliances:

- 3 for an excessive number of defective ties in a 39-foot segment of track at Mile 61.4, Mile 69.1, and Mile 72.5, and
- 1 for narrow gauge, also at Mile 72.5.

The letter further identified 88 concerns, 83% of which were for narrow-gauge conditions approaching the minimum allowable limit of ½ inch. CP took safety action on 27 August 2021. On 25 March 2022, TC issued a letter acknowledging the action taken.

On 23 March 2022, TC inspected the track from Mile 94.38 to Mile 116.21 (21.83 miles) and issued a letter of non-compliance. It listed 2 non-compliances:

- 1 for a cross-level deviation on tangent track over a distance of 43 feet at Mile 96.8 (verified at $1^{7}/_{16}$ inch), and
- 1 for a joint mismatch on the top or gauge side of the rail exceeding the allowable limit (measured at $^{7}/_{16}$ inch).

The letter further identified 11 additional concerns, 45% of which were for narrow-gauge conditions. Of particular note were 2 narrow-gauge conditions measuring almost a ½ inch in the vicinity of the derailment (1 at Mile 97.41 and 1 at Mile 97.54).[20] According to TC records, CP reported that it had completed the required safety action.

1.8 Track maintenance near Mile 97.4 the week before the occurrence

On 08 July 2022, the day after the ATGMS inspection that found 2 urgent AL/62 defects at Mile 97.41, a CP track supervisor conducted a targeted visual inspection and confirmed the presence of the urgent defects. The supervisor placed a 10 mph temporary slow order, and a plan was made to install 15 ties, non-consecutively, over 200 feet to break up clusters of defective ties. The ties were installed that same day, and the track was surfaced.[21]

On 10 July, 580 anchors were installed over approximately 500 feet at Mile 96.6. These anchors were added to existing anchors to increase longitudinal rail restraint.

The temporary slow order was raised to 25 mph on 10 July and then cancelled on 11 July.

On 12 July, the track was visually inspected, and no evidence of rail movement was observed.

The TEC Book provides guidance on correcting an AL/62 defect occurring in hot weather, indicating that this may require rail to be restressed (see section 1.9.5). In this occurrence, the repairs did not include cutting the rail.

1.9 Thermal stress in continuous welded rail

Steel expands under heat and contracts under cold conditions. Forces exerted by expansion and contraction of the rail place stress on the track structure. Excessive compressive forces can cause track buckling, while excessive tensile forces due to contraction can lead to pull-apart (joint failures) and broken rails.

The main contributor to thermal stress in rail is ambient temperature, particularly in extreme temperature conditions. When CWR is exposed to an increase in ambient temperature, the temperature of the rails will increase accordingly. In the summer months,

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[20] On Class 4 track, narrow-gauge measurements over ½ inch exceed TSR minimum track standards for Class 3, 4, and 5 track. CP defines any defect that exceeds track standards as an urgent defect.

[21] Surfacing involves lifting ties and tamping ballast under them by mechanical means, to restore proper track surface.

especially under direct sunlight, if the exposure is sustained over a long period, the resulting rail temperature can exceed the ambient temperature. In hot, sunny weather, the rail temperature can be estimated as ambient temperature plus 17 °C (30 °F).[22]

In jointed rail (rails joined mechanically with joint bars fastened with bolts), the joints provide space for the rail to expand and contract. In CWR, rail sections are welded together and the rails are anchored in place. This securement ensures that rail movement is restrained against the longitudinal forces exerted by the passage of trains, but it also limits the rail's ability to expand and contract in response to changes in temperature.

There are 2 important aspects to managing the effects of thermal stress in CWR: rail temperature and track securement.

1.9.1 Rail temperature

Rail temperature is one of the most critical factors in managing thermal stress in CWR.

There are 2 important measurements of rail temperature:

- the temperature at which the rail is largely free of thermally induced stress due to expansion or contraction; this is known as the rail neutral temperature (RNT), and
- the predetermined temperature at which the rail should be installed so that it remains relatively stress-free all year round, considering the regional ambient temperature extremes to which it will be exposed; this is known as the preferred rail laying temperature (PRLT).

The length of a rail can be mechanically or thermally altered so that it is stress-free at any ambient temperature. This practice is required to ensure that, once CWR is installed and secured, its RNT corresponds to the desired PRLT.

Railways set an optimal PRLT for each of their subdivisions, taking into account local factors that may increase the track's vulnerability to compressive stress, and any history of track buckles or rail pull-apart. For the track on the Brooks Subdivision, the PRLT is 95 °F (35 °C).[23]

1.9.2 Rail support and securement

To limit the effects of thermal stress, it is also important that the rail be properly supported and secured. Restraining the rail longitudinally and laterally depends on having ties in good condition, the correct tie plates, sufficient spikes and anchors, clean crushed-rock ballast, and good track ballast shoulders. If one or more of these track components do not have the capacity to withstand the stress exerted by the longitudinal forces, the force of the stress can overcome the lateral stability of the track and create misalignment.

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[22] Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 18 May 2022), Section 8: Prevention of Track Buckling, Figure 8.1, p. 51.

Ibid., Appendix 1: Preferred Rail Laying Temperature by Subdivision, p. 136.

Rail anchors hold the rail in place and transmit the longitudinal forces including those generated by the passage of a train to the ties. The ties, embedded in the ballast, absorb the forces that are then transferred to the subgrade. If one or more of the track components is not contributing to the expected resistance, the potential for track irregularities increases. For example, if the ties to which the anchors are applied are not in good condition, the anchors will not provide the expected restraint. Similarly, worn, rounded ballast stones with relatively few fracture faces might not provide adequate restraint for the ties embedded in the ballast. Sound ballast usually has crushed rock that has rough, angular surfaces, which allow the stones to interlock with the ties and with each other to form a stable subgrade.

Expansion of rail is best accommodated over a long section of track. If the expansion is constrained or confined by a rigid and solidly fixed location, compressive forces can build up in the rail.

1.9.3 Drift in rail neutral temperature over time

Over a rail's service life, ambient temperature variations and traffic-induced rail movements will invariably cause a redistribution of the internal stresses in the rail. On hills, rail generally moves slowly downhill, resulting in an excessively low stress-free temperature at the bottom of the hill and an excessively high stress-free temperature at the top.

CWR can also drift into tension or compression as a result of track maintenance activities such as lining, surfacing, ballast cleaning, and tie replacement. Even if the track is not worked on, the rail temperature will drift away from the PRLT under various conditions such as worn, defective, or insufficient anchors; poor-quality or insufficient ballast; or soft subgrade.

When the RNT has drifted well below the PRLT, compressive stresses in the rail begin to build at a lower ambient temperature. Performing maintenance work under these conditions increases the potential for a track buckle.

1.9.4 Thermal stress monitoring

To detect signs of thermal stress in CWR, railway workers routinely perform visual inspections by hi-rail vehicles.

Visual inspections rely on judgment by track maintenance workers who must check the track structure for physical signs of degradation, such as misalignments, poor contact of the rail anchors, and movement of the rail through the rail anchors. However, physical signs of thermal stress may not always be visible from a moving hi-rail vehicle.

Currently, no simple, direct method exists for measuring thermal stress in rails. When excessive stress is identified, adjustments are necessary, but the process can be time-consuming.

For adjusting tensile stress, the common technique involves cutting the rail with a rail saw when the ambient temperature is below the PRLT. Once the rail has contracted and reached a stress-free state at RNT, it can be readjusted to the desired PRLT. To relieve compressive stress, a section of rail may be cut out using a torch, and a temporary plug rail installed. After cooling to or below the RNT, the rail can then be readjusted to the PRLT. To date, an accurate, easily deployable, and non-destructive longitudinal force measurement system—either vehicle or track-borne—is not available, making the development of CWR force measurement a major worldwide research need.[24]

If the track is determined to be under compressive stress, either through visual inspections or destructive methods, the stress in the rail must be readjusted.

1.9.5 Adjusting the rail neutral temperature

The process of readjusting stress in the rail is called either destressing or restressing. Once the stress is released, any excess rail is removed, or new rail is added if required. The rails are then welded back together and re-anchored.

The Red Book includes several sections that are relevant to restressing:

- Section 7.7.3(a)(v) includes restressing as a possible permanent repair option for track buckles.[25]
- Section 8 has extensive detail on hot weather inspections and the signs and symptoms of track buckle risk.[26] It prescribes an immediate 10 mph slow order or to stop traffic at locations where the track condition indicates that a track buckle is imminent.[27]
- Appendix 4 provides extensive detail on restressing CWR in all environments.
- Section 8.5 provides instructions for inspecting and restressing the track in advance of program tie installations, and for when CWR was laid at a rail temperature more than 20 °F (about 6.7 °C) below the PRLT, such as during winter rail repairs when rail heaters are not available. It states, in part:

> a. In advance of program tie installation, an inspection must be conducted to determine locations within the limits of the planned work requiring restressing of CWR.
>
> i. Perform the inspection when the ambient air temperature is above [PRLT – 10 °F] when rail stress problems would be evident.
>
> […]

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[24] A. Kish and G. Samavedam, *Track Buckling Prevention: Theory, Safety Concepts, and Applications*. U.S. Department of Transportation, Federal Railroad Administration, Report DOT/FRA/ORD – 13/16, 2013

[25] Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 18 May 2022), Section 8, subsection 7.7.3: Permanent Repair, p. 41.

[26] Ibid., subsections 8.1.0: General, 8.2.0: Hot Weather Track Inspections, 8.3.0: Hot weather Temporary Slow Orders, and 8.4.0: Placing Temporary Speed Restrictions Accounting for Track Work, pp. 47-49.

[27] Ibid., subsection 8.2.1: Inspection Requirements. p. 48.

> b. In advance of program tie installation, cut and restress rail according to Appendix 4 all locations identified in the inspection conducted to determine locations within the limits of the planned work requiring restressing of CWR.[28]

According to the Red Book, a rail must be restressed when, over time, its RNT has drifted 20 °F (about 6.7 °C) below PRLT or lower.[29]

1.9.6 Track maintenance activities impacting rail neutral temperature near Mile 97.4

CP provided records of the track maintenance activities it conducted in the 2004 to 2022 timeframe in the vicinity of Mile 97.4. The data was further reviewed to focus on activities that disturbed the track (and hence likely impacted RNT) between the east switch at Bassano and the fixed point at Mile 97.48 on the Brooks Subdivision (Table 3).

Table 3. Selected track maintenance activities conducted near Mile 97.4 of the Brooks Subdivision from 2004 to 2022

Date	Activity	Comment
2013 (from 10 to 13 June)	Major localized tie program	Involved the installation of 1256 ties from Mile 96.0 to Mile 98.0, and a further 231 ties from Mile 97.0 to Mile 98.5. Documents provided did not include information about the RNT when this work was completed.
2013, 2014, 2018, 2019, and 2021	Track surfacing and lining	Track surfacing is conducted to correct surface and alignment conditions.
2015, 2018, and 2019	CWR maintenance	In 2015 and 2019, CWR maintenance work was performed at Mile 97.4 and involved adjusting RNT. In 2018, CWR work was conducted at Mile 97.48.
2021 (September)	Ballast distribution and shoulder cleaning	The work was completed from Mile 95.7 to Mile 100.0; how much of this work was completed near Mile 97.4 is not documented.
2022 (16 June)	Track surfacing and lining	About 1800 feet of track was surfaced from Mile 97.2 to Mile 97.7. The work was performed after automatic geometry testing was completed on 09 June.
2022 (09 July)	Track surfacing and lining	About 900 feet of track was surfaced from Mile 97.0 to Mile 97.1.

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[28] Ibid., subsection 8.5.1: Planning and Executing Restressing in Advance of Program Work, p. 50.

[29] Ibid., Appendix 14: Estimated Rail Neutral Temperature, pp. 163–165.

2022 (10 July)	Spot tie replacement	Work performed over 200 feet of track near Mile 97.5.

1.10 Track buckles

A track buckle (Figure 6) is a large lateral misalignment of the rails[30] that occurs when longitudinal compressive stresses build up in the rail and overcome the lateral resistance of the track structure.

Figure 6. Track buckle (Source: TSB Railway Investigation Report R14E0081)

Track buckles usually initiate at small alignment deviations. Lateral alignment defects in rails reduce the track's buckling strength.

Track buckle lengths can range from 40 to 60 feet and can result in a lateral deflection of the track by up to 30 inches. These misalignments can cause derailments because trains travelling at typical operating speeds cannot negotiate track that has shifted laterally. Both curved and tangent tracks are susceptible to buckling. Tangent track tends to buckle explosively with a large deflection, whereas the curved track may buckle progressively with comparatively smaller lateral displacements.[31] Buckles are predominantly lateral, but may occasionally be vertical.

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[30] A. Kish and W. Mui, *Track Buckling Research*, John A. Volpe National Transportation Systems Center, Federal Railroad Administration, Office of Research and Development, United States (09 July 2003) at https://rosap.ntl.bts.gov/view/dot/11985 (last accessed 17 December 2024).

[31] A. Kish and G. Samavedam, *Track Buckling Prevention: Theory, Safety Concepts, and Applications* Office of Research and Development, Federal Railroad Administration (March 2013) at https://railroads.dot.gov/elibrary/track-buckling-prevention-theory-safety-concepts-and-applications (last accessed 17 December 2024).

Excessive thermal loads can result in buckling, referred to as static buckling. However, buckles are typically caused by a combination of the following factors:

- weakened track conditions,
- elevated compressive rail forces, and
- train dynamic forces.

Train vehicle forces due to rolling friction, braking, acceleration, and wheel flanging on curves or areas of narrow gauge can contribute to track buckling by exerting additional longitudinal forces on the track structure. In curved sections of track, rolling stock can contribute to buckling by increasing lateral wheel forces.

Additionally, during the rolling contact between the wheel and rail, heat is generated at the contact surface, due to friction. The amount of heat generated increases in proportion to the number of axles on a train, the wheel loading, and the train speed, and is more pronounced when the rail surface is dry and clean. Although the overall increase in rail temperature due to rolling contact is not significant compared with the effects of high ambient temperatures, especially when the rail is exposed to direct sunlight, the heat generated nonetheless creates additional compressive stress in the rails.

Buckling due to the combination of thermal and vehicle forces is called dynamic or vehicle-induced buckling. Train dynamics also tend to increase the size of alignment deviations, which can trigger the buckling process. Most buckling derailments tend to occur after half to two thirds of a train's length has passed over an area susceptible to buckling.[32]

1.10.1 Locations prone to track buckling

Some areas are known to be more susceptible to compressive stress, and hence more prone to track buckling. CP's Red Book states, in part:

> **8.1.3 Locations Prone to Track Buckling**
>
> a. Pay particular attention to the following locations that are more prone to track buckles:
>
> […]
>
> v. Bottom of a heavy grade or bottom of a sag.
>
> […]
>
> viii. Areas having a history of lateral instability.
>
> ix. Recently disturbed track e.g. tie replacements, surfacing etc.
>
> […]

---

[32] G. Wolf, *The Complete Field Guide to Modern Derailment Investigation* (Wolf Railway Consulting, 08 March 2021), p. 289.

> xiv. Fixed locations such as turnouts, crossings and bridges. In particular, pay special attention to locations where rail has been observed to be moving through rail anchors towards a fixed location.[33]

The conditions described above were present in the vicinity of Mile 97.4.

1.10.2 Indicators of potential track buckles

The Red Book lists common indicators of potential track buckles. They include

> i. Wavy rail.
>
> ii. New line deviations, such as short flat spots in curve or kinks in tangent track.[34]
>
> iii. Gaps or voids in ballast at end of ties.
>
> iv. Rail base not properly seated in the plates.
>
> v. Rail running through the anchors […].
>
> vi. Churning of ballast caused by tie movement resulting in gauge and line kinks.
>
> vii. Longitudinal movement of switch point in relation to stock rail, resulting in improper switch adjustment. [35]

Several of the factors listed above were observed in the vicinity of Mile 97.4 (see section 1.2.1, *Condition of the track in the vicinity of the derailment*).

1.10.3 Previous derailments due to a track buckle on federally regulated railway track

Between January 2012 and December 2021, 45 occurrences were reported to the TSB in which a track buckle was a cause or contributing factor in a derailment:

- 80% (36 occurrences) were main-track derailments.
- 24% (11 occurrences) involved more than 10 cars.
- 91% (41 occurrences) involved Class 1 freight railways.
- 31% (14 occurrences) involved CP trains.
- 87% (39 occurrences) occurred in the months of May, June, and July.
- 29% (13 occurrences) occurred in Alberta.
- The average was 4.5 per year, but occurrences varied from 2 to 8 per year.

The TSB produced investigation reports for 3 of these 45 derailments (TSB occurrences R21M0027, R14W0137, and R14E0081). A brief summary of these occurrences and applicable findings from the investigations is provided in Appendix A.

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[33] Canadian Pacific Railway Company, *Red Book of Track & Structures Requirements* (revised 18 May 2022), Section 8: Prevention of Track Buckling, subsection 8.1.3: Locations Prone to Track Buckling, p. 47.

[34] Although not stated explicitly, AL/62 defects are another example of new line deviations.

[35] Ibid., subsection 8.1.2: Indicators of Potential Track Buckles, p. 47.

Up to and including this derailment, there have been no injuries associated with track buckle derailments reported to the TSB.

1.11 Increased size of unit grain trains

The size of unit grain trains has greatly increased in the last decade.

Ten years ago, a typical grain train hauled about 100 to 112 cars, measured about 7000 feet, and weighed less than 15 000 tons.

In June 2018, CP announced plans to invest in new, high-capacity grain hopper cars that could handle more than 15% greater volume and 10% greater load weight than the old Government of Canada cars they would replace, while featuring a shorter car-body frame that would allow more cars in a train of the same length.[36] CP noted that safety was a key consideration in the introduction of the new high-capacity cars.

In December 2018, CP unveiled its new high-efficiency product (HEP) 8500-foot train model.[37] With 147 loaded high-capacity hopper cars, the HEP train would weigh about 21 000 tons.

By 2020, CP was operating much longer and heavier unit grain trains on some of its subdivisions; one of the largest carried 243 loaded grain cars, weighed 33 320 tons, and measured 14 219 feet (54% longer than the 8500-foot HEP train design unveiled in December 2018).

On the Brooks Subdivision, CP operated its first large unit train composed of high-capacity hopper cars in April 2020. From January 2021 to 13 July 2022, 21 of these trains travelled westward through Bassano, including the occurrence train. These trains had over 200 loaded hopper cars, measured at least 10 500 feet, and weighed over 25 000 tons.

1.12 Train traffic volume on the Brooks Subdivision

CP historical records show that, in 2015, total traffic volume on the Brooks Subdivision was about 53.5 million gross ton-miles per mile (MGTM/M). By 2018, annual gross tonnage had increased by about 27% (14.4 MGTM/M). Annual volumes from 2018 to 2022 were sustained at an increased rate, with an average value of 69.4 MGTM/M. Westward traffic, which consists predominantly of loaded unit trains, is approximately 60% of total traffic volume (Table 4).

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[36] *Dedicated to Grain*, letter from Canadian Pacific Railway Company to the Minister of Transport, 31 July 2018.

[37] Canadian Pacific Railway Company, "CP showcases new high-capacity hopper cars, High Efficiency Product train" (04 December 2018), at https://www.cpkcr.com/en/media/CP-showcases-new-high-capacity-hopper-cars-High-Efficiency-Product-train (last accessed 17 December 2024).

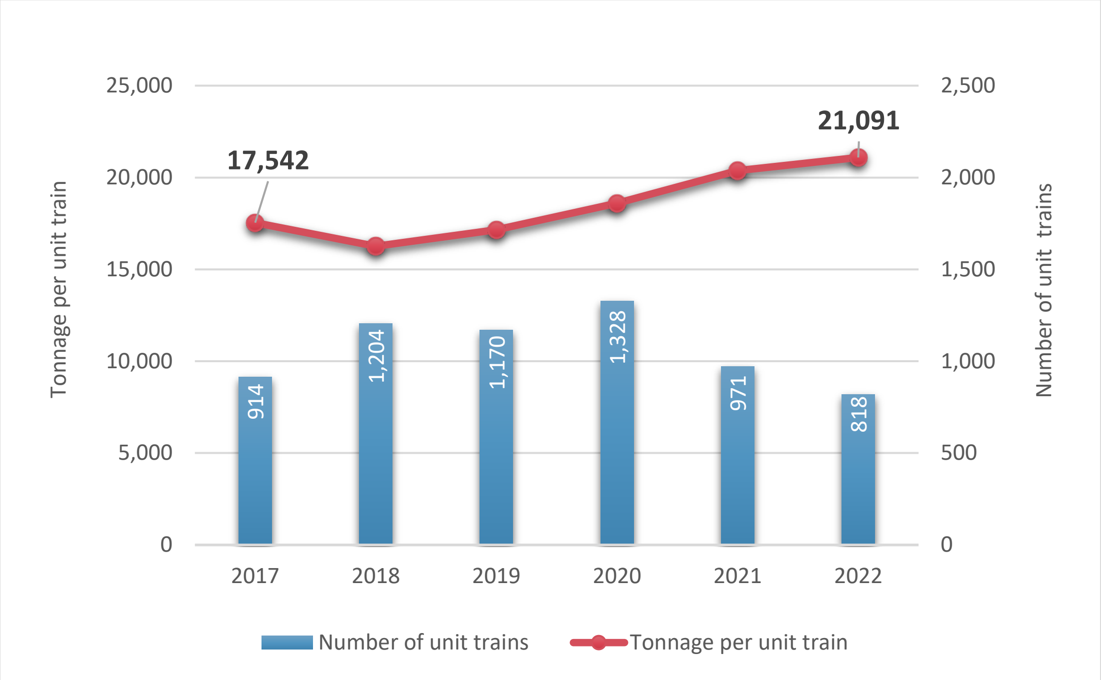
Table 4. Freight traffic volumes on the Brooks Subdivision from 2015 to 2022 (Data source: Canadian Pacific)

Year	Total traffic volume (million gross ton-miles per mile)	Westward traffic volume	
		Million gross ton-miles per mile	Percentage of total traffic volume (%, rounded to the nearest whole number)
2015	53.5	30.8	58
2016	52.3	30.7	59
2017	54.9	32.9	60
2018	67.9	40.0	59
2019	65.3	40.3	62
2020	74.8	46.0	61
2021	70.1	42.3	60
2022	68.9	41.0	60

1.12.1 Increased volumes of westbound loaded unit trains

CP historical data also show that the number of westbound unit trains (grain and potash) increased steadily between 2017 and 2020, peaking at 1328 trains. Between 2018 and 2021, the tonnage per train also increased. In 2021, tonnage per train continued to increase, even though the number of trains in 2022 was almost 40% below the 2020 count (Figure 7).

Figure 7. Number and tonnage of westbound unit trains on the Brooks Subdivision from 2017 to 2022, showing that train tonnage increased year-over-year from 2018 to 2022, while the number of trains peaked in 2020, but had dropped by nearly 40% from this peak in 2022 (Source: TSB)



The traffic volume and tonnage data for 2020 and 2021 reflect CP's introduction on the subdivision of large, loaded unit grain trains composed of 200 or more high-capacity hopper cars.

In addition to increased unit grain and potash traffic, there was also a significant increase in the number and tonnage of other[38] westbound unit trains in 2018 (Table 5), however the trend has stabilized at a level higher than 2017.

Table 5. Number of other westbound unit trains on the Brooks Subdivision 2017 to 2021 (Data source: Canadian Pacific)

Year	Number of other trains
2017	15
2018	159
2019	86
2020	74
2021	56

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[38] In this instance "other" pertains to loaded unit commodity trains of specific product types. The information is included as an indicator of increased tonnage over the subdivision.

1.13 Track–train dynamics

Track–train dynamics (TTD) involve the interaction between the track and a moving train. It encompasses all the dynamic forces resulting from this interaction and the factors that contribute to these forces, including train size (length and weight), train makeup (such as weight distribution), train speed, train handling (such as acceleration and deceleration), rail car characteristics, track alignment (such as grades and curves), track stiffness, track condition (such as corrugation and deviations in geometry), and prevailing climatic conditions.

An important aspect of TTD is heavy axle loading (HAL) and the loads imposed on the track under the passage of rolling stock. This creates a momentary stress on the track structure, which leads to gradual deterioration (wear, fatigue, and settlement) of this infrastructure.

Specifically, HAL creates a vertical stress point at the wheel–rail interface that momentarily deflects the rail and track structure vertically under the loaded weight of passing rail car wheels. The stress points are concentrated under the trucks of the rail cars. On a moving train, the deflection creates a moving longitudinal wave along the track structure: the track is pushed downward under the leading trucks, then lifted upward (this upward lift is known as the "central wave") as the centre of the car passes, and is pushed downward again under the trailing trucks. The amplitude of the wave under each car depends on the axle loads, the spacing between the axles, the truck centre spacing, and the stiffness of the track structure. This wave pattern is repeated with the passage of each car and provides the track little or no opportunity for complete elastic recovery.[39]

When looking at the train as a whole, the wave pattern begins with a precession wave at the front of the train, followed by the troughs and crests generated by each rail car, and ending with a recession wave behind the train.

The vehicle's vertical forces on the track structure also dynamically affect the track's lateral resistance. Specifically, the tie–ballast structure directly underneath the weight of the vehicle wheels are subject to an increased vertical load, which serves to increase the track's lateral resistance along this track segment. However, in the area of the central wave, the tie–ballast structure between the car trucks is momentarily unloaded, due to the dynamic uplift wave; this reduces the lateral resistance along this track segment. Thus, the track's lateral resistance fluctuates with the troughs and crests of the wave: it is greater directly under the wheels and lower between the trucks.[40] Figure 8 illustrates these dynamics.

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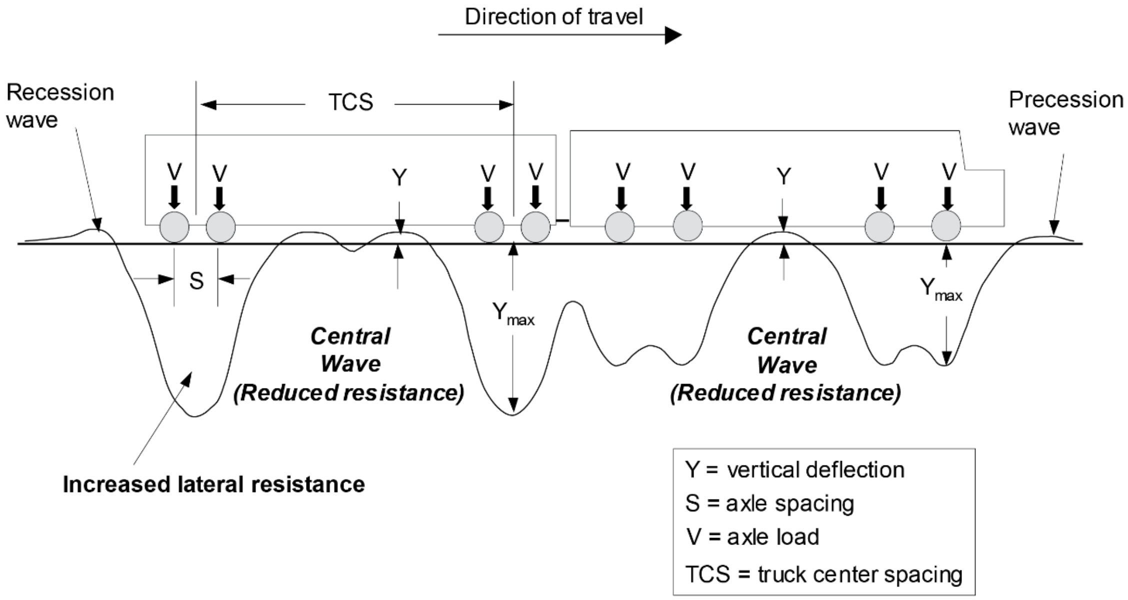
[39] Elastic recovery is the track's ability to return to its original shape after being loaded and unloaded.

[40] A. Kish and G. Samavedam, *Track Buckling Prevention: Theory, Safety Concepts, and Applications*, Office of Research and Development, Federal Railroad Administration (March 2013) at https://railroads.dot.gov/elibrary/track-buckling-prevention-theory-safety-concepts-and-applications (last accessed 17 December 2024)

Figure 8. Diagram of the track–train dynamics associated with heavy axle loading, showing the wave effect under a moving train and the points within the wave where lateral resistance is increased and were it is reduced [Source: A. Kish and G. Samavedam, *Track Buckling Prevention: Theory, Safety Concepts, and Applications*, Office of Research and Development, Federal Railroad Administration (March 2013) at https://railroads.dot.gov/elibrary/track-buckling-prevention-theory-safety-concepts-and-applications (last accessed 17 December 2024)]



The effects of HAL are more pronounced under the passage of longer and heavier trains:

- Trains with a higher number of rail cars subject the rails to a greater number of load cycles (generally referred to as cyclic loading).
- Heavier rail cars impose a greater load on the rails.

Longer and heavier trains, therefore, have a more significant and compounding deterioration effect on the track infrastructure in general. This initially manifests itself by the presence of lifted spikes, loose anchoring, rail creep, worn ballast, skewed and plate-cut ties, etc. As the track further degrades, track defects eventually develop and progress with the passage of each additional train unless regular track maintenance is increased.

Loaded unit trains, in particular, have a more pronounced cyclic loading effect and can hasten permanent track deformation. On a loaded unit train, the cars typically have very similar lengths and weights, and are of a similar design (car bodies, trucks, and suspension systems), and hence they interact with the track in a similar manner. Therefore, each rail car on a unit train responds to track irregularities in the same manner as the previous car, thereby creating a repetitive hammering effect, concentrating cumulative impacts at whatever irregularities are encountered in the track structure.

The combined impact of HAL and cyclic loading depends on several factors, including:

- the magnitude of the applied cyclic stress (axle and truck spacing, weight of the train and individual rail cars);
- the duration of loading (the total number of axles);

- the loading frequency (the number of trains per year);
- the condition of the track structure, ballast, and sub-ballast; and
- the track's stiffness.

1.13.1 TSB Railway Safety Issues Investigation Report SII R05-01

In response to a series of train derailments on secondary main lines involving broken rails in the winter of 2003–04, the TSB carried out a safety issues investigation.[41] The investigation established a significant relationship between rail defects and the level of unit train traffic and found that the effect of increasing unit train traffic had not been attenuated through regular maintenance. The same circumstances could also apply to main-line track. The investigation also identified the following:

- Railways recognized that the rate of track degradation accelerated with increases in unit train tonnage. However, an appropriate balance between increased track degradation and timely infrastructure maintenance and/or renewal was not always achieved.
- Compliance with the TSR in and of itself was insufficient to ensure safety because it did not provide a means to anticipate changing conditions such as increased traffic over the long term.
- There was a need for more proactive safety management system (SMS) processes to anticipate operational conditions that could lead to a degradation of safety margins.

1.13.2 TSB investigations of derailments involving track degradation from cyclic loading

The effects of loaded unit trains on track, and particularly cyclic loading, are not unknown in railway operations, especially in corridors where loaded and often unidirectional unit trains regularly operate. While these effects have been contributing factors in track wear for many decades, they were not consistently highlighted in railway derailment investigations. However, on subdivisions where significant increases in train traffic have occurred, given the operation of increasingly heavy-tonnage unit trains, the effects of cyclic loading have gained focus in derailment investigations.

From 2004 to 2021, the TSB has investigated 6 occurrences on federally regulated railways in which cyclic loading, or factors that increase cyclic loading such as an increased size and number of trains, was associated with a cause or contributing factor (Appendix B).

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[41] TSB Railway Safety Issues Investigation Report SII R05-01: *Analysis of Secondary Main-Line Derailments and the Relationship to Bulk Tonnage Traffic* (2005).

1.14 Track inspector and supervisor training

1.14.1 Regulatory requirements

Regulatory requirements for the training and certification of track supervisors and track inspectors are specified in the TSR and the *Railway Safety Management System Regulations, 2015* (the SMS Regulations).

1.14.1.1 Requirements under the *Rules Respecting Track Safety*

Under the TSR, railways are required to ensure that track inspectors and track supervisors are qualified and certified to perform their duties.[42] This entails, in part, ensuring that employees in these positions know and understand the requirements of the TSR, as well as the company's requirements, including procedures and standards for track inspections and maintenance. The recertification interval for track inspectors and track supervisors must not exceed 3 years.[43]

1.14.1.2 Requirements under the *Railway Safety Management System Regulations, 2015*

Sections 25 to 27 of the SMS Regulations require a railway company to have a process for managing knowledge.

Section 25 states, in part:

> **25 (1)** A railway company must establish a list setting out
>
> (a) the duties that are essential to safe railway operations;
>
> (b) the positions in the railway company that have responsibility for the performance of each of those duties; and
>
> (c) the skills and qualifications required to perform each of those duties safely.[44]

Under Section 27, railway companies are required to include the following in their SMS:

> (a) a plan for ensuring that an employee who performs any of the duties referred to in paragraph 25(1)(a) has the skills and qualifications referred to in paragraph 25(1)(c) and the knowledge referred to in subsection 25(3);
>
> (b) a method for verifying that an employee who performs any of the duties referred to in paragraph 25(1)(a) has the skills and qualifications referred to in paragraph 25(1)(c) and the knowledge referred to in subsection 25(3);
>
> […]
>
> (d) a method for verifying that a person referred to in section 26 has the knowledge referred to in that section.[45]

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[42] *Rules Respecting Track Safety* (approved by Transport Canada 02 February 2021, effective 01 February 2022), Part I, section 7: Knowledge, Qualifications and Certification, pp. 7–8.

[43] Ibid., section 7.4, p. 7.

[44] Transport Canada, SOR/2015-26, *Railway Safety Management System Regulations, 2015*, subsection 25(1).

[45] Ibid., section 27.

1.14.2 Canadian Pacific training for track inspectors and supervisors

CP's training program for track inspectors and supervisors includes training on railway track safety rules; CP track engineering standards (the Red Book); and CWR installation, maintenance, and repair theory. Training specific to CP engineering standards instructs employees how to perform the tasks associated with track defect identification and repair.

The course on CWR frequently references Red Book content. Topics include the effect of temperature on rail, thermal stress limits of properly maintained track, track buckles, PRLT, RNT, restressing, and the probable outcomes if defects are left unattended. The course and exercises should take 1 day to complete. A closer examination of the course content with respect to track misalignments, track buckles, and restressing revealed the following:

- It discusses the need to restress when rail repairs are conducted at temperatures below the PRLT range or when planned program work is performed; it also indicates that track buckles can be a consequence of not restressing the rail under these circumstances.
- It does not specifically mention the need to consider restressing when there are obvious signs of rail stress.
- It does not specifically mention that permanent repairs of track buckles could involve cutting out rail and restressing.

Neither the Red Book training nor the CWR training cover the difference between loaded and unloaded track geometry measurements. The training material does not specifically address the TSR requirement to adjust all unloaded measurement to accommodate for track movement under load. There is no record that track inspectors or supervisors received specific training on the TEC Book, although this book was available to track inspectors and supervisors as a reference document.

Training may be otherwise provided through on-the-job training, mentorship, or other activities not documented in the employee trainee record.

1.14.3 Training, knowledge, and oversight of the inspectors and supervisors in this occurrence

According to track inspection records provided by CP, 5 track inspectors/supervisors conducted inspections, maintenance, and repair work in the vicinity of the derailment between April and July 2022.[46] These employees had from 3 to 20 years of experience in track inspection and maintenance and were familiar with their territory.

The TSB's review of the training records for these employees revealed the following:

- All 5 employees had received training on the TSR in the previous 3 years.

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[46] Track visual inspections and general maintenance are typically conducted by inspectors and supervisors working alone.

- Three of the 5 employees had received training on CP's Red Book in 2014; none had received training on the engineering standards in force at the time of the derailment (the Red Book was revised in October 2019, and again in May 2022).
- Three of the 5 employees had completed the course on CWR within the previous 3 years.

CP uses a variety of employee oversight methods to evaluate the knowledge of qualified employees and confirm that they are applying their knowledge to comply with requirements. Examples of these methods include efficiency tests, ride-alongs, and briefings. With respect to the track inspectors/supervisors in this occurrence, employee efficiency testing records for January to June 2022 indicate that

- 3 of the 5 employees had been tested,
- 29 of the 32 tests (91 %) had been conducted on a single employee, and
- none of the employees had been tested specifically on CWR maintenance.

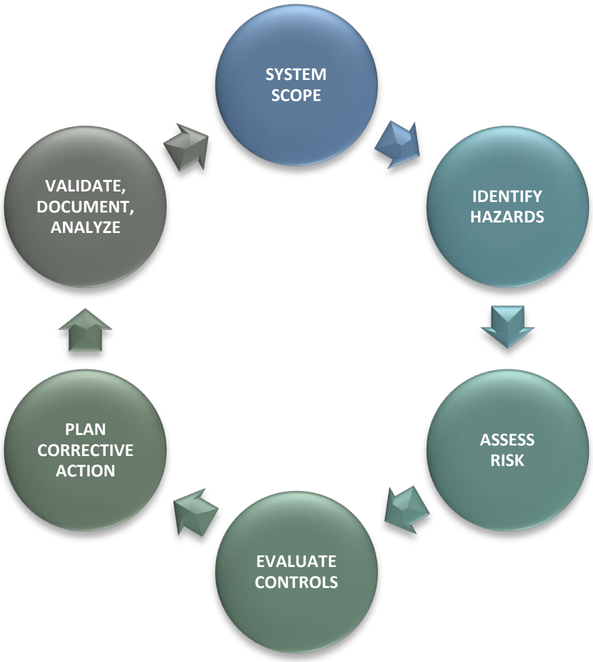
Oversight and accountability for ensuring employees are trained and qualified rest with Engineering management.

1.15 Safety management systems

SMS is an internationally recognized framework that allows companies to identify hazards, manage risks, and make operations safer. An SMS improves safety by building on existing processes, demonstrating corporate due diligence, and growing the overall safety culture.

Safety management is a systemic approach to safety—engaging, but not limited to, a continuous safety improvement process (Figure 9). An effective SMS incorporates the 4 pillars of safety management: safety policy and objectives, safety risk management, safety assurance, and safety promotion.

Figure 9. Generic safety management system model (Source: TSB)



The SMS framework is not new to Canadian railway operations; SMS regulations were introduced in 2001. In 2013, the investigation into a fatal derailment in Lac-Mégantic, Quebec[47] identified shortcomings in the regulations that led to their revision in 2015. Under the *Railway Safety Management System Regulations, 2015* (SMS Regulations), railway companies must develop an SMS that includes processes for identifying safety concerns,[48] for conducting risk assessments, and for implementing and evaluating remedial (safety) action.[49,50]

Safety action taken is one step in the SMS process. Therefore, it is expected that any safety action taken as a result of an occurrence is part of a continuous safety improvement process, where the scope of change is defined, the hazards are identified, the risks are assessed, the safety actions are implemented and evaluated, and the entire process is documented. Consequently, the effectiveness of a safety action to reduce the likelihood or severity of an undesired event can be objectively measured.

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[47] TSB Rail Transportation Safety Investigation Report R13D0054.

[48] The *Railway Safety Management System Regulations, 2015* do not define "safety concern", but provide trends, emerging trends, and repetitive situations as examples.

[49] Transport Canada, SOR/2015-26, *Railway Safety Management System Regulations, 2015*, section 5, p. 3.

[50] In the context of safety management systems, the terms "remedial action" and "safety action" are generally understood to be synonymous, and both describe actions taken to improve safety. The *Railway Safety Management System Regulations, 2015* uses the term "remedial action," whereas, in this report, the term "safety action" is used.

The TSB investigates occurrences to identify safety deficiencies, including those in a company's SMS, and reports on instances in which the safety system could manage risk more effectively or proactively.

1.15.1 Canadian Pacific's safety management system

CP, in accordance with the SMS Regulations, has developed and implemented an SMS, which includes a risk assessment policy and procedure. The risk assessment procedure outlines the conditions under which a risk assessment must be conducted. It states, in part:

> A confidential risk assessment must be conducted […] whenever:
>
> - A "Safety Concern" (i.e. a hazard or condition that may present a direct safety risk to employees, or pose a threat to safe railway operations) is identified through analysis of safety data;
> - A proposed change to CP Operations that could:
>   - introduce a new hazard to the workplace resulting in adverse effects;
>   - negatively impact or contravene any existing policy, procedure, rule or work practice used to meet regulatory compliance or any CP requirements or standards;
>   - create or increase a direct safety risk to employees, railway property, property transported by the railway, the public or property adjacent to the railway; or
>   - require authority by a regulatory agency to implement.
>
> A risk assessment must be performed as soon as practicable after the identification of a safety concern; prior to the commencement of the work affected or implementation of the proposed changes. […][51]

CP's risk assessment policy and procedure requires the company to engage its risk assessment process when a "safety concern" is identified through the analysis of safety data. Therefore, if safety data related to a specific operational change is not analyzed, there is no regulatory requirement to engage the company's risk assessment process.

When HEP grain trains were introduced in 2018, CP did not consider the new car design, nor the effects of cyclic loading from the HEP trains on track infrastructure, as an operational change requiring the analysis of safety data for the assessment of a "safety concern,".[52]

Similarly, in 2020, when CP began operating much longer and heavier unit grain trains from Winnipeg to Thunder Bay, a route that travels through peatlands (a type of terrain known to have inherently low load-bearing capacity), the company SMS process was not engaged

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[51] Canadian Pacific Railway Company, *Risk Assessment Procedure*, version 2.0 (last revised 30 June 2017), section 2.1.1, p. 2.

[52] Before operating the HEP trains, CP conducted a simulation focused on the company's instructions for distributed power trains. The simulation considered track-structure conditions in keeping with regulatory requirements and CP's track standards and was conducted for loaded unit grain trains up to 168 cars on the route west from Bowden, Alberta, to Vancouver, British Columbia.

prior to 1 of these trains derailing near Ignace, Ontario. Following the occurrence the railway conducted simulations and required that distributed power grain trains consisting of 224 cars or more always be equipped with a tail-end remote locomotive. The possible effects of cyclic heavy axle loading on the track infrastructure was not considered, and the company continued to operate the long, heavy trains on this route.[53]

In 2021, when the railway expanded the operation of unit grain trains consisting of high-capacity hopper cars on the route from Medicine Hat to Vancouver, no assessment was conducted to determine whether there were safety concerns about the track's ability to withstand the increased dynamic forces associated with the operation of these trains.

Train traffic data for the Brooks Subdivision from 2018 to 2022 indicate a significant increase in the number and tonnage of other unit trains. As part of its investigation of this occurrence, the TSB asked CP to provide records of its SMS process, and more specifically any records related to the introduction of unit grain trains consisting of high-capacity hopper cars and to the significant increase in other unit train frequency on the Brooks Subdivision. The TSB also requested records of CP's process for managing knowledge, in particular with respect to track workers' knowledge of CWR maintenance. CP reported that there were no safety risk management processes conducted specific to the introduction or increased frequency of unit trains on the Brooks Subdivision, or to the management of track workers' knowledge.

Since 2015, when the SMS Regulations were last revised, the TSB has investigated 7 other occurrences in which CP did not engage its safety risk management process to consider whether operational changes required a risk assessment.[54]

1.15.2 Previous recommendation related to Canadian Pacific's safety management system

Following its investigation of an occurrence on 04 February 2019, in which a CP freight train derailed on a steep descending grade near Field, British Columbia, and the 3 crew members on board were fatally injured,[55] the Board found that, when hazards are not identified—either through reporting, data trend analysis, or by evaluating the impact of operational changes—and when the risks that they present are not rigorously assessed, gaps in the safety defences can remain unmitigated, increasing the risk of accidents.

The Board also found that, until CP's overall corporate safety culture and SMS framework incorporate a means to comprehensively identify hazards, including the review of safety reports and data trend analysis, and assess risks before making operational changes, the effectiveness of CP's SMS will not be fully realized. Therefore, the Board recommended that

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[53] TSB Rail Transportation Safety Investigation Report R20W0102.

[54] TSB rail transportation safety investigation reports R20W0102, R19C0015, R19C0002, R18H0039, R17D0123, R16W0074, and R16C0065.

[55] TSB Rail Transportation Safety Investigation Report R19C0015.

> the Department of Transport require Canadian Pacific Railway Company to demonstrate that its safety management system can effectively identify hazards arising from operations using all available information, including employee hazard reports and data trends; assess the associated risks; and implement mitigation measures and validate that they are effective.
>
> **TSB Recommendation R22-03**

In its December 2023 response to this recommendation, TC indicated that it completed significant actions toward assessing the effectiveness of CP's SMS. CP is required to provide periodic filings containing information to support TC in assessing the efficacy of its processes for identifying safety concerns and assessing risk. TC also concluded 2 targeted audits of CP's SMS, focused on the company's processes for identifying safety concerns and assessing risks. TC has communicated to CP its expectations relating to the implementation of a corrective action plan, including the amendment of its process for identifying safety concerns. Once TC receives the amended process, the department will assess its completeness and verify its implementation.

In its February 2024 assessment of TC's response, the Board indicated that it is encouraged that TC conducted targeted audits of CP's SMS and looks forward to receiving the results of TC's review and assessment of CP's amended SMS processes. The Board assessed TC's response to Recommendation R22-03 as having **Satisfactory Intent**.[56]

1.16 TSB Watchlist

The TSB Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer.

Safety management is a Watchlist 2022 issue.

Federally regulated railways have been required since 2001 to have an SMS, and regulatory requirements were significantly enhanced in 2015. However, the expected changes in safety culture and safety improvements with the implementation of SMSs have not yet been demonstrated by the industry. Since Watchlist 2020, TSB investigations have continued to identify hazards that are not always recognized and subsequently risk-assessed by operators so that effective risk mitigations can be taken. As a result, the TSB has determined that railway companies' SMSs are not yet effectively identifying hazards and mitigating risks in rail transportation.

ACTION REQUIRED

The issue of safety management in rail transportation will remain on the Watchlist until operators demonstrate to TC that their SMSs are effective.

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[56] TSB Recommendation R22-03: Risk management through hazard identification, data trend analysis, and risk assessments at https://www.tsb.gc.ca/eng/recommandations-recommendations/rail/2022/rec-r2203.html (last accessed 17 December 2024).

2.0 ANALYSIS

Train 301-222 was operated in a manner that was consistent with company and regulatory requirements. A review of the mechanical and train operating information did not reveal equipment defects or train handling issues. Therefore, the analysis will focus on a combination of causes and contributing factors related to track-buckle derailments, on company practices for proactive management and maintenance of track, and on the engagement of its safety management system.

2.1 The occurrence

On 13 July 2022, at approximately 1618, Canadian Pacific Railway Company (CP) train 301-222 was travelling westward at 44 mph on the Brooks Subdivision on an average 0.34% ascending grade when a train-initiated emergency brake application occurred, near Bassano, Alberta.

Video from the lead locomotive showed no obvious signs of a pre-existing track anomaly. However, when the mid-train locomotive passed by Mile 97.4, there was a noticeable side-to-side sway in the recorded image, indicating a track anomaly at this location.

The side-to-side swaying motion of the mid-train remote locomotive, a recent alignment issue at the same location, and the history of track conditions in the area, such as gauge and securement issues, support the determination that the track buckled under the train.

Finding as to causes and contributing factors

The track buckled under the passage of CP train 301-222, leading to the derailment of 41 cars at Mile 97.4 of the Brooks Subdivision, near Bassano, Alberta.

2.2 Condition of the track

The track in the vicinity of the derailment site showed signs of degradation consistent with many years in service and high volumes of loaded unit train traffic.

From 2015 to 2017, the already high annual train traffic of 50 million gross ton-miles per mile (MGTM/M) jumped to roughly 70 MGTM/M, a 25% increase likely to accelerate track deterioration.

Post-occurrence visual inspection of the track in the area of the derailment found deteriorated track conditions: contaminated and worn ballast; lifted spikes; rail creep marks; missing or loose anchoring; and skewed, worn, and plate-cut ties.

Signs of deterioration had also been evident in track inspection records for more than a year. Records from track geometry inspections conducted using heavy geometry inspection vehicles (HGIVs)—track evaluation cars and cars equipped with the autonomous track geometry measurement system (ATGMS)—documented frequent urgent narrow-gauge conditions. Narrow-gauge conditions may be indicative of insufficient track securement and elevated compressive forces. Reports from track inspections conducted by Transport

Canada (TC) on the Brooks Subdivision in 2021 and 2022, and the non-compliance letters issued after these inspections, echoed CP's own geometry testing results.

Degraded track infrastructure reduces the track's lateral restraint and ability to withstand longitudinal compressive forces and is a common factor in track-buckle derailments.

According to CP maintenance records, the rail at the derailment location had been in service for 26 years. A tie program was last completed in 2013, and there are records of welding/joint elimination, surfacing, new rail installation, and ballast work. Surfacing conducted following the June 2022 ATGMS inspection indicated that CP was aware of, and attempting to address, track surface conditions.

Finding as to causes and contributing factors

The track structure in the vicinity of the derailment was in a deteriorated condition that reduced lateral stability and made the track more susceptible to buckling.

2.3 Compressive stress in the rail

In the vicinity of the derailment, there were several factors present known to make the rail more susceptible to compressive stress, creating a higher risk for the development of a track buckle. This section of track was at the bottom of a sag that had been recently disturbed by spot tie replacements to correct an urgent track misalignment. It was also constrained by 2 fixed locations: the area where the switch was installed at the east end of the Bassano siding the previous year, and the area where firm rail securement—elastic fastening and anchoring every tie—remained in place after the removal of the turnout that had connected the former Irricana Subdivision to the Brooks Subdivision.

Track vulnerable to compressive stress must be closely monitored. In this occurrence, inspections by HGIV found recurring non-urgent alignment defects (i.e., priority AL/62 exceptions) and a high number of gauge defects, both of which are characteristic of track under compressive stress.

Signs of compressive stress can also be identified through visual inspections; such signs include rail alignment issues, gaps in the ballast at the end and along the length of the ties, and rail running through anchors. The track in the vicinity of the derailment location exhibited these conditions. CP's records, however, suggest that the visual inspections might have been focused on rail joints, as 80% of the documented inspection results were related to rail joint conditions.

High compressive stress can be identified through monitoring the difference between the preferred rail laying temperature (PRLT)—the target design temperature at installation as determined by the railway for an operating area—and the rail neutral temperature (RNT)—the temperature at which the rail is free of any stress due to rail expansion or compression. If the RNT is found to be significantly lower than the PRLT, the affected rail must be restressed. However, currently, no simple, direct method exists for measuring thermal stress in rails. When excessive stress is identified, adjustments are necessary, but the process can be time-consuming.

In this occurrence, the last major tie program in the area of the derailment was completed in 2013. Since then, surfacing was conducted through the derailment location every 1 to 2 years, including in the month before the occurrence, an activity that is known to affect RNT. Continuous welded rail (CWR) maintenance activities that involved restressing were conducted in 2015, 2018, and 2019.

Finding as to causes and contributing factors

The location of the derailment had risk factors known to elevate the likelihood of a track buckle, and although periodic destressing had occurred up to 3 years before the occurrence, persistent compressive forces in the rail had since built up.

2.3.1 Thermal stress and drift in rail neutral temperature

Thermal rail stress occurs when the steel rail is subjected to sustained elevated temperatures or significant temperature variations. Under heat, the rail steel expands and, if this expansion cannot be accommodated, compressive forces result.

The main contributors to elevated temperatures in rail are ambient temperature and direct exposure to sunlight. When the temperature of CWR increases above the RNT, the rail will expand and generate a thermal compressive force in proportion to the temperature increase. TSB data show that 90% of reported track-buckle derailments occur from May to July, with the highest number of occurrences in July.

The daytime high temperature in the Bassano area quickly rose from 14.9 °C on 04 July to 31.6 °C on 12 July, a rise of 16.7 °C. In the week before the derailment, nighttime temperatures dropped as low as 6.9 °C on 12 July, while the peak daytime temperature remained high (from 24.8 °C to 31.6 °C), subjecting the rail to cycles of thermal compressive stress. CP's *Track Evaluation Cars Guidelines for Defects and Reports* (TEC Book) notes that correcting alignment defects in hot weather may require rail to be cut, but this guidance is absent from the section on preventing track buckles in CP's *Red Book of Track & Structures Requirements* (Red Book). There is no evidence of formal training to track employees on the TEC Book.

CWR installation procedures are intended to ensure that the track structure will withstand thermal stress from ambient temperature under normal conditions, including sustained high ambient temperatures, or significant variations in ambient temperatures. However, a track's vulnerability to thermal compressive forces increases if the RNT has reduced significantly from the original PRLT. RNT naturally changes over time. During a rail's service life, ambient temperature variations, traffic-induced rail movement, and track maintenance activities can cause a redistribution of the internal stress in the rail, which may lower the RNT.

Given that the main track at Bassano had been in service since 2019 without restressing, that traffic volumes had significantly increased, and that the track in the area where the derailment occurred had a number of factors known to elevate track buckle risk and RNT drift, it is likely that its RNT had drifted over the years. In the weeks leading up to the occurrence, there were signs that the track was vulnerable to thermal stress. Persistent non-urgent track alignment conditions (priority AL/62 exceptions) at Mile 97.41, which had been present for at least a year, suddenly progressed to urgent defects. The change coincided with a rapid 11 °C rise in peak ambient temperature to 25.8 °C, which is high, but not extreme, for the region. The magnitude of the temperature change should not have been sufficient to have caused the progression of track defect from priority to urgent. The fact that it did was an indication that the track was particularly vulnerable to thermal stress and that the RNT had likely drifted well below the PRLT.

Yet, when the urgent alignment defects were repaired the next day, the scope of the repair did not include measuring RNT. CP's Red Book did not require that such measurements be taken when conducting spot repairs of track defects. Currently, no simple, direct method exists for measuring thermal stress in rails. When excessive stress is identified, adjustments are necessary, but the process can be time-consuming.

The urgent defects were repaired in accordance with company instructions. Nevertheless, within days of completing the repairs, the track went out of alignment again, causing a track-buckle derailment.

Finding as to risk

If company track maintenance practices do not include requirements for monitoring and proactively adjusting RNT at locations and times of the year when rail is particularly vulnerable to compressive forces, there is a risk that excessive compressive forces will result in track-buckle derailments.

2.4 Track geometry inspections

2.4.1 Analysis of inspection data

Track defects identified through inspections are usually corrected through spot repairs. However, repairing individual defects in isolation might not address a more systemic underlying condition. To uncover systemic issues, the data must be analyzed for trends.

In this occurrence:

- Inspections using a gauge restraint measuring system found predominantly wide-gauge defects, whereas inspections over the same area of track conducted using ATGMS predominantly found narrow-gauge defects. Such differences were noted in inspections taken days apart, such as the inspection with a gauge restraint measuring system on 04 July 2022 and inspections by ATGMS on 07 July 2022. In at least 1 instance, the measurements at the same location differed by more than 1.5 inches, indicating reduced lateral stability.
- Inspections by ATGMS conducted in the heat of the day were finding significantly more urgent defects than inspections conducted during the cooler hours did. The

discrepancies suggest that the rail was significantly affected by variations in ambient temperature, which may be a symptom of thermal stress in the rail consistent with uncontrolled RNT.

These trends indicate that the track was vulnerable to compressive forces. However, there is no evidence that CP was systematically analyzing automated inspection data for signs of elevated compressive stress or drift in RNT.

Finding as to risk

Without trend analysis of track inspection data, there is a risk that an underlying condition, such as elevated compressive stress in the rails, will not be proactively identified and corrected, leading to track failures and derailments.

2.4.2 Amendments to track geometry measurements taken under load

CP conducted track geometry measurements in accordance with the requirements under the *Rules Respecting Track Safety*, also known as the Track Safety Rules (TSR). The measurements were taken under a loaded condition through a combination of occupied track evaluation car and ATGMS car inspections.

Track geometry can also be inspected using light geometry inspection vehicles, typically a hi-rail vehicle. However, the TSR require that unloaded track measurements obtained by light geometry inspection vehicles or done manually by a track worker be adjusted to account for dynamic loading conditions; the amount of rail movement that would occur while the track is under a loaded condition must be added to the measurements of the unloaded track.

The Red Book makes no mention of this TSR requirement, nor is there evidence that track maintenance workers on the Brooks Subdivision were taking this requirement into consideration. However, CP's TEC Book (last updated in 2014) notes that unloaded track measurements may differ from loaded values, provides a table for correcting unloaded to loaded values, and indicates that, in hot weather, alignment repairs may require rail to be cut out.

CP track geometry inspection data for the Brooks Subdivision indicate that ATGMS inspection reports were amended. In many cases, amended reports included notations of verified track gauge. The investigation determined that urgent measurements reported by ATGMS were being manually inspected. When the results of the manual inspection were different from the ATGMS measurements, the ATGMS measurements were amended without correcting for loaded conditions. This practice, in effect, gives greater weight to the results obtained when the track is not under load. Consequently, urgent defects were sometimes downgraded to a lower priority rather than repaired.

Finding as to risk

When company instructions and practices allow manual unloaded measurement to supersede track geometry measurements taken under load using a high-precision HGIV, urgent track defects may not be identified and proactively repaired, increasing the likelihood of preventable track-related derailments.

2.5 Track–train dynamics

CWR track-buckle derailments involve a combination of degraded track, elevated compressive forces, and track–train dynamic forces. These forces arise from the interaction between the track and a moving train due to train size (length and weight), train makeup (such as weight distribution), train speed, train handling (such as acceleration and deceleration), rail car characteristics, track alignment (grades and curves), track stiffness, track condition (such as corrugation and deviations in geometry), and prevailing climatic conditions.

A review of the locomotive event recorder data for the occurrence train indicated that there were no elevated in-train longitudinal or lateral forces at the time the derailment occurred:

- The head-end portion of the train (25% of the train length) was descending an average 0.4% grade, with the balance of the train ascending an average 0.34% grade. Consequently, there was minimal to no slack action.
- The train was operating under Trip Optimizer control; the throttle had been gradually advanced to the notch 8 position about 3.5 minutes before the train-initiated emergency brake application.
- The tractive effort forces were distributed among the 3 locomotive consists, at the head, middle, and rear of the train.

A review of the video from the forward-facing camera on the lead locomotive gave no indication of a track defect when the locomotive passed over Mile 97.4. However, when the mid-train locomotives passed over the same location, there was a noticeable side-to-side sway in the recorded video, indicating that a misalignment developed progressively under the train. The misalignment continued to grow with the additional passage of cars until it was too large for the 116th car to negotiate. This progressive buckling is consistent with cyclic and heavy axle loading, a TTD phenomenon that creates a dynamic uplift between the car trucks, contributing to a momentary loss of lateral restraint. These effects are especially pronounced under the passage of unit trains.

The train in this occurrence was a unit train hauling 203 high-capacity hopper cars, the first train of this design to travel through Bassano since the urgent alignment defects were repaired a few days earlier. Its overall loading effect on the track structure would have exceeded that of the previous trains that had recently passed through the area. Furthermore, the occurrence train was traversing the area at a time when daytime temperature, and consequently the thermal compressive stress from the ambient temperature, was at its highest. The thermal compressive forces—in combination with the reduced lateral resistance due to the dynamic uplift effect under the moving train and the unloading of the tie-ballast structure between the car trucks—created a condition that made the track vulnerable to a track buckle.

Finding as to causes and contributing factors

Elevated compressive rail forces on degraded track, along with track–train dynamics that reduced the track's lateral resistance under the moving train, caused the track to shift out of alignment and buckle.

2.6 Track maintenance training

According to the *Railway Safety Management Systems Regulations, 2015* (the SMS Regulations), railway companies must have a process for managing knowledge, including a method for verifying that employees who perform safety-critical duties have the skills, knowledge, and qualifications required to perform these duties safely.

The training records for employees conducting inspection, maintenance, and repair work in the vicinity of the derailment in prior months indicate that these employees were not all receiving the required training or retraining in a timely manner or, if the training had been received, that it was not reliably documented.

For instance, records show only 3 of the 5 employees had completed the course on CWR installation, maintenance, and repair theory within the previous 3 years; some employees had last received training on CP's track-engineering standards in 2014, before the broad adoption of ATGMS technology, while other employees had never received this training.

In addition, employee-efficiency test records indicate that only 1 employee was being regularly evaluated on track maintenance and repair knowledge.

With respect to the CWR training content, the course material is silent on urgent alignment defects and the need to assess and manage RNT when repairing them. The procedures for responding to a track buckle are described, but the material does not discuss their prevention through restressing, except in the context of repairing cold rails. Red Book section 7.7.3(a)(v) includes restressing as a possible permanent repair option, but this is not referenced in CWR training content. Neither Red Book training nor CWR training covers the difference between loaded and unloaded track geometry measurements in depth, although it is addressed in the TEC Book.

Track inspection and repair, as practiced on the Brooks Subdivision, demonstrate that the company was not reliably identifying, monitoring, and managing compressive forces, including monitoring RNT and restressing. Furthermore, because the employees were not undergoing regular performance testing on current standards, the gaps in knowledge were not identified, assessed, or corrected.

Finding as to risk

Without adequate track worker knowledge management, gaps in employee training and performance testing might not be identified, increasing the risk that employees will not have the skills required to perform their duties in a manner that ensures safe railway operations.

2.7 Increased size and frequency of unit trains on the subdivision

In its Railway Safety Issues Investigation (SII) R05-01, the TSB studied a series of occurrences and identified an imbalance between infrastructure maintenance and increases in the volume of unit traffic on secondary main track. The SII identified that, although railways recognized that the rate of track degradation accelerated with increases in unit train tonnage, an appropriate balance between increased track degradation and timely infrastructure maintenance and/or renewal was not always achieved. Corridor assessments must consider the strength of the infrastructure and the stresses introduced by passing trains. The investigation highlighted that compliance with the TSR alone, which sets minimum requirements, was not sufficient to ensure safety and emphasized the need for proactive SMS processes to anticipate operational changes and conditions that could lead to a degradation of safety margins.

Since SII R05-01 was released in 2006, the average length and weight of unit trains, a train type known to accelerate track degradation, has increased significantly. High-efficiency product unit grain trains, introduced to normal train operations in 2018, average over 25 000 tons and 8500 feet. The introduction of heavier and longer trains reduces the number of train movements needed to move increasing volumes of bulk traffic.

On the Brooks Subdivision, westbound unit train traffic significantly increased in 2018 and remained high thereafter. Annual gross tonnage jumped by about 24% (13.0 million gross ton-miles per mile), and annual volumes from 2018 to 2022 averaged 69.4 million gross ton-miles per mile. Although the absolute number of trains peaked in 2020, tonnage per train continued to increase: between 2018 and 2022, more tonnage was moved even though the number of trains per year in 2022 was almost 40% below the 2020 count. The occurrence train was hauling 203 loaded cars, weighed 27 962 tons and measured 11 758 feet.

Even though CP track inspection frequency exceeds TSR minimum requirements, the track in the vicinity of the derailment was in a degraded condition and exhibiting risk factors associated with compressive stresses that could lead to a track buckle derailment. CP did not assess the risks associated with the increase in train traffic and in the size of unit trains. Consequently, the railway did not anticipate the need for increased track maintenance; maintenance practices were reactive and relied on lagging indicators, such as track defect reports.

Finding as to risk

Without proactive assessment of track infrastructure and the risks associated with increases in tonnage and the operation of heavier and longer unit trains, it may not be possible to identify and correct inadequate track maintenance practices, increasing the risk of track infrastructure failures.

2.8 Safety management systems

Since 2010, the TSB Watchlist has emphasized the need for SMSs to be implemented effectively, to ensure that hazards are proactively identified and risks are mitigated.

Effective risk management does not completely eliminate risk. Rather, it manages risk to a level as low as reasonably practicable. Therefore, when the TSB identifies a hazard that likely contributed to an occurrence or risk of occurrence, it must consider whether the company's SMS was applied and, if so, whether it was applied effectively.

In this occurrence, there were opportunities to identify hazards and safety concerns related to the introduction of long, heavy unit trains on the Brooks Subdivision. Such trains had previously been associated with rapid deterioration of the track structure and had been found in other TSB investigation reports to be a contributing factor in derailments. The track geometry inspection reports were giving clear indications that the track was vulnerable to compressive forces, yet these reports were not analyzed for trends or safety concerns. There is no documented evidence that CP's SMS process was applied.

This is the 8th TSB investigation since 2015 to consider CP's process for conducting risk assessments when introducing operational changes.

Finding as to risk

Without proactive risk management of railway operations, including risk assessments, company SMS practices, will remain ineffective at reducing main-track train derailments.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. The track buckled under the passage of CP train 301-222, leading to the derailment of 41 cars at Mile 97.4 of the Brooks Subdivision, near Bassano, Alberta.
2. The track structure in the vicinity of the derailment was in a deteriorated condition that reduced lateral stability and made the track more susceptible to buckling.
3. The location of the derailment had risk factors known to elevate the likelihood of a track buckle, and although periodic restressing had occurred up to 3 years before the occurrence, persistent compressive forces in the rail had since built up.
4. Elevated compressive rail forces on degraded track, along with track–train dynamics that reduced the track's lateral resistance under the moving train, caused the track to shift out of alignment and buckle.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If company track maintenance practices do not include requirements for monitoring and proactively adjusting rail neutral temperature at locations and times of the year when rail is particularly vulnerable to compressive forces, there is a risk that excessive compressive forces will result in track-buckle derailments.
2. Without trend analysis of track inspection data, there is a risk that an underlying condition, such as elevated compressive stress in the rails, will not be proactively identified and corrected, leading to track failures and derailments.
3. When company instructions and practices allow manual unloaded measurement to supersede track geometry measurements taken under load using a high-precision heavy geometry inspection vehicles, urgent track defects may not be identified and proactively repaired, increasing the likelihood of preventable track-related derailments.
4. Without adequate track worker knowledge management, gaps in employee training and performance testing might not be identified, increasing the risk that employees will not have the skills required to perform their duties in a manner that ensures safe railway operations.

5. Without proactive assessment of track infrastructure and the risks associated with increases in tonnage and the operation of heavier and longer unit trains, it may not be possible to identify and correct inadequate track maintenance practices, increasing the risk of track infrastructure failures.

6. Without proactive risk management of railway operations, including risk assessments, company safety management system practices will remain ineffective at reducing main-track train derailments.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Canadian Pacific

Following the occurrence, Canadian Pacific Railway Company (CP) took the following safety actions:

- It undertook track renewal program work, including program work for cross ties, rail anchors and shoulder ballast, as well as weld destressing and spot undercutting.
- It amended the engineering managers' safety accountabilities to include a train ride (on a track evaluation car, work train, or revenue train) once a month, starting 10 August 2022 and for the remainder of that year, as an additional means to evaluate track condition.
- It updated the continuous welded rail maintenance forms in its Digital Track Network (DTN) system to reflect locations that need to be restressed pending final repair.
- It made changes to the training for supervisors of track inspection. These changes include additional training on geometry defects and the importance of loaded vs unloaded measurements (and how to adjust for unloaded measurements). Scenarios have been added related to broken rails, reference marks, and CWR restressing that teach, among others, the importance of properly maintaining CWR, how to make sure rail is stressed correctly to the PRLT, how to validate reference marks, and how to record the information in DTN.
- On 24 March 2023, it issued engineering safety bulletin ESBT061, *CWR Maintenance Records Expectations* with an accompanying instruction sheet, *DTN Job Aid for CWR Maintenance Task*, to reinforce and clarify requirements for documenting CWR maintenance activities.
- On 12 July 2023, it issued engineering safety bulletin ESBT140, *Red Book Change: Section 8.7.5 Speed Restriction Requirements*, which provides clearer instructions for when the maximum rail temperature is expected to be above the preferred rail laying temperature, minus 15 °F in the next 24 hours.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 14 November 2024. It was officially released on 22 January 2025.

Visit the Transportation Safety Board of Canada's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the key safety issues that need to be addressed to make Canada's transportation system even safer. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

APPENDICES

Appendix A – TSB investigations of derailments related to track buckles

Between January 2012 and December 2021, the TSB has investigated 3 occurrences in which a track buckle was considered a cause or contributing factor.

R21M0027

On 21 August 2021, Canadian National Railway Company (CN) train B73041-15 was travelling eastward at 39 mph on the Napadogan Subdivision when it derailed 30 hopper cars loaded with potash at around Mile 18.9 near Pangburn Station, New Brunswick. There were no dangerous goods involved and no fire. No one was injured.[57]

The train was a distributed power unit potash train with 133 cars weighing almost 20 000 tons. On the day of the occurrence, ambient daytime high temperatures were between 25 °C and 31 °C. At the point of derailment, there were signs of rail movement across the anchors and ties. Track work had been conducted at the point of derailment 2 days earlier.

The investigation report presented the following findings, among others:

- The derailment occurred when the track buckled under the train as it was decelerating on a descending grade near Pangburn Station.
- High ambient temperatures and exposure to direct sunlight on the day of the occurrence contributed to the buildup of compressive thermal stress in the rail.
- The neutral temperature of the rail had decreased over its service life, creating instability at lower ambient temperatures and reducing the ability of the rail to resist buckling when subjected to compressive stress.
- Degraded condition of rail anchoring on the non-destressed sections reduced the strength of the track and its resistance to movement.

R14W0137

On 23 May 2014, CN freight train M34641-23 was proceeding eastward on the Fort Frances Subdivision when 35 cars derailed at Mile 93.38 near Fort Frances, Ontario. The derailed cars included 2 tank cars loaded with molten sulphur (UN2448), 1 of which was punctured and released product. The product ignited a small grass fire that subsequently burned itself out. There were no injuries.[58]

The investigation report presented the following findings, among others:

- The accident occurred when the track misalignment at Mile 93.38 buckled sharply beneath the train, leading to the derailment of the 31st to 65th cars.

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[57] TSB Rail Transportation Safety Investigation Report R21M0027.

[58] TSB Railway Investigation Report R14W0137.

- The track structure in the vicinity of the derailment was in poor condition, with defective ties, fouled ballast, and ineffective anchoring of the rail.
- The highest year-to-date ambient temperature was recorded on the day of the accident, with a large temperature change that further increased compressive stress within the rail.
- Despite an increase in rail traffic and tonnage, track maintenance programs were delayed on track that was already showing signs of deterioration, and no mitigation strategies such as speed reductions were applied.
- Despite CN's company maintenance and Transport Canada's (TC's) regulatory inspection activities before the accident, the weakened track structure was not being adequately repaired or being protected by slow orders.

After the derailment, TC issued a Notice and Order restricting CN train operations. The Notice and Order included restricting speeds between Mile 90.1 and Mile 142.8 to Class 2 track maximums (20 mph for freight trains).

CN conducted a walking inspection with 8 professional engineers and mobilized 2 tie gangs to replace ties between Mile 87.0 and Mile 143.6 of the Fort Frances Subdivision. TC reviewed the measures taken and deemed the safety action satisfactory to address the unsafe conditions.

R14E0081

On 11 June 2014, eastbound CN freight train A41851-11 derailed the last 20 cars at Mile 202.3 of the Slave Lake Subdivision in Faust, Alberta. The last 17 cars were residue tank cars that had last carried diesel fuel (UN1202). There was no release of product and there were no injuries. Approximately 1200 feet of track was damaged.

The investigation report presented the following findings as to causes and contributing factors:

- The derailment occurred when the track shifted laterally under the passing train.
- The track buckled as a result of an irregular rail anchoring pattern, a build-up of compressive stress in the rail, and a relatively unstable peat bog subgrade, which was unable to restrain the longitudinal forces generated by the train descending the grade.
- High compressive stress had likely accumulated in the track structure as a result of repeated exposure to longitudinal forces from previous trains that had used dynamic braking at this location.
- The condition of the track could not handle the traffic levels that had increased significantly on this corridor since 2013, in advance of the recommended infrastructure improvements.

It also presented the following risk finding:

- If the impact of increased traffic levels on track infrastructure is not adequately assessed or mitigated, the risk of derailments will increase.

Appendix B – TSB investigations where cyclic loading or increased train size and frequency was considered a cause or contributing factor

From 2004 to 2021, the TSB investigated 6 occurrences in which cyclic loading, or increased train size and frequency, was considered a cause or contributing factor.

R20W0102: On 25 May 2020, 53 cars of Canadian Pacific Railway Company (CP) train 320-227, a unit train, derailed near Ignace, Ontario. The train was hauling 222 hopper cars loaded with grain, measured 12 896 feet and weighed 30 307 tons. The TSB investigation of this occurrence determined that the bearing capacity of the soft, saturated peat subgrade was likely exceeded, resulting in a sudden subgrade failure that led to the derailment. The investigation report indicates that "[t]he operation of loaded high-capacity rail cars in unit train consists created longer periods of cyclic loading and provided little opportunity for the elastic recovery of this track with geometry anomalies, accelerating the deterioration of the inherently unstable track subgrade."

R20V0005: On 07 January 2020, 34 cars of Canadian National Railway Company (CN) train U79351-06 loaded with wood pellets derailed near Kitwanga, British Columbia. The TSB investigation report of this occurrence concludes that, given the annual tonnage on the Bulkley Subdivision and the frequency of loaded unit train operations, it is likely that unit train traffic accelerated the development and deterioration of priority wide-gauge conditions in the 6° left-hand curve where the derailment occurred.

R19W0320: On 09 December 2019, 34 cars of CP train 516-398, a loaded petroleum crude oil unit train, derailed near Guernsey, Saskatchewan. The TSB investigation of this occurrence determined that the derailment occurred when the train traversed a gap in the south rail; it also found that, despite regular track visual inspections and rail flaw detection testing, the broken south rail, which was in territory governed by the occupancy control system, went undetected before the arrival of the train. The investigation report indicated that, between 2015 and 2019, rail traffic tonnage on the Sutherland Subdivision increased by 60% and the transport of crude oil increased by over 66 000 car loads. In the findings as to risk, the report highlights the need for company risk assessments to adequately consider increases in traffic tonnage, the use of heavier rail cars, and the potential for more rapidly degrading infrastructure.

R14W0137: On 23 May 2014, CN freight train M34641-23 derailed 35 cars at Fort Frances, Ontario. The TSB investigation of this occurrence determined that the derailment occurred when a track misalignment at Mile 93.38 buckled sharply beneath the train. The investigation report indicated that "[d]espite an increase in rail traffic and tonnage, track maintenance programs were delayed on track that was already showing signs of deterioration, and no mitigation strategies such as speed reductions were applied."

R14E0081: On 11 June 2014, CN mixed freight train A41851-11 derailed the last 20 cars in Faust, Alberta. The TSB investigation of this occurrence determined that the derailment occurred when the track shifted laterally under the passing train. The investigation report indicates that “[t]he condition of the track could not handle the traffic levels that had increased significantly on this corridor since 2013, in advance of the recommended infrastructure improvements.”

R04Q0040: On 17 August 2004, 18 tank cars of CN train U-781-21-17, a petroleum product unit train, derailed in the marshy area of the Grande Plée Bleue, near Saint-Henri-de-Lévis, Quebec. The TSB investigation report of this occurrence indicates that “[t]rack subgrade settlements accumulated under the repeated effect of loads gradually resulted in distortion and realignment of peat fibres, which most likely led to the sudden punching failure.”