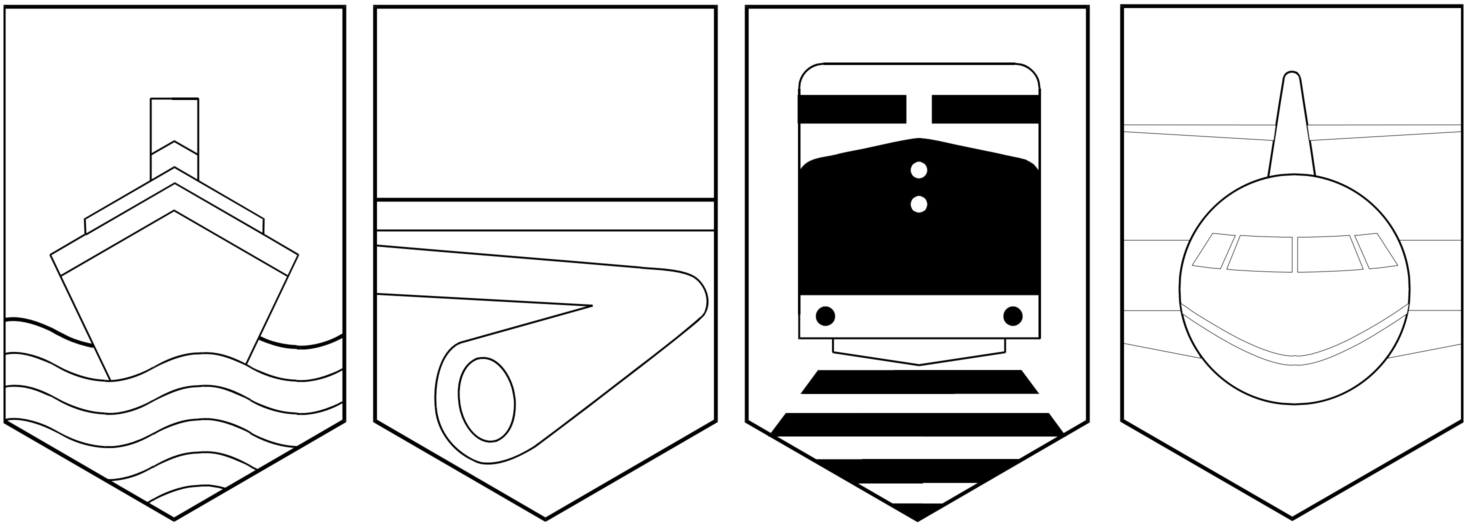
Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada



RAILWAY OCCURRENCE REPORT

CN NORTH AMERICA
DERAILMENT
TRAIN NO. 336-KP-24
MILE 89.7, KINGHORN SUBDIVISION
ORIENT BAY, ONTARIO
25 APRIL 1994

REPORT NUMBER R94W0101

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

It is not the function of the Board to assign fault or determine civil or criminal liability. However, the Board must not refrain from fully reporting on the causes and contributing factors merely because fault or liability might be inferred from the Board's findings.

INDEPENDENCE

To enable the public to have confidence in the transportation accident investigation process, it is essential that the investigating agency be, and be seen to be, independent and free from any conflicts of interest when it investigates accidents, identifies safety deficiencies, and makes safety recommendations. Independence is a key feature of the TSB. The Board reports to Parliament through the President of the Queen's Privy Council for Canada and is separate from other government agencies and departments. Its independence enables it to be fully objective in arriving at its conclusions and recommendations.

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Railway Occurrence Report

CN North America
Derailment
Train No. 336-KP-24
Mile 89.7, Kinghorn Subdivision
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Synopsis

CN North America (CN) eastward freight train No. 336-KP-24 encountered a large roadbed washout and derailed two locomotives and 15 loaded cars at Mile 89.7 of the Kinghorn Subdivision at Orient Bay, Ontario. The train crew could not stop the train before the depression. Three employees sustained injuries.

The Board determined that water infiltration of the subgrade of glaciolacustrine silts and clays resulted in the subgrade becoming saturated to a higher elevation than previously experienced and, as a result, it became unstable and slumped, leaving a large depression under the track. The water that infiltrated the subgrade originated from a build-up caused by a partially blocked culvert and possibly from underground low-pressure sources.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 The Accident

CN North America (CN) train No. 336-KP-24, destined for MacMillan Yard in Toronto, Ontario, departed from Thunder Bay, Ontario, at approximately 0810 eastern daylight time (EDT) on 25 April 1994. Shortly after 1240 EDT, as the train rounded a left-hand curve in the direction of travel just past Orient Bay, Ontario, at Mile 91.0 of the Kinghorn Subdivision, the conductor saw indications of a large washout in the roadbed, about 1,000 feet ahead. He advised the locomotive engineer who made an emergency brake application.

At the time of the brake application, train speed was approximately 34 mph. The train could not be stopped before the depression and the lead locomotive went into the hole at a speed of approximately 26 mph. Fifteen cars on the head end derailed in a space of about 400 feet, some coming to rest on top of the locomotives.

Nearby residents heard the crash and, after notifying the railway company and the police, proceeded to the scene to render assistance. The locomotive engineer freed himself from the wreckage and pulled the assistant conductor from between the second locomotive and a car. The conductor was trapped in the operating compartment of the lead locomotive and was freed by first responders. The crew was airlifted to Thunder Bay for medical treatment.

1.2 Injuries

The assistant conductor and the conductor sustained serious injuries. The locomotive engineer received minor injuries.

1.3 Damage to Equipment

Fourteen cars and two locomotives were destroyed. The 15th car was slightly damaged.

1.4 Other Damage

Approximately 500 feet of track was destroyed. Also, some rolls of paper fell onto the right-of-way and the ice on Lake Nipigon and, as a result, were damaged.

About 1,500 gallons of diesel fuel leaked from the locomotives into Lake Nipigon. The spill was contained by staff of the Ontario Ministry of Environment and most of the diesel fuel was recovered.

1.5 Personnel Information

The train crew consisted of a conductor and a locomotive engineer, both of whom were positioned in the lead locomotive, and an assistant conductor who was in the second locomotive. All crew members were qualified for their respective positions and met fitness and rest standards established to ensure the safe operation of trains.

1.6 Train Information

The train included 2 locomotives, 79 loaded and 8 empty cars. It weighed approximately 8,421 tons and was 5,051 feet in length.

1.7 Particulars of the Track

The Kinghorn Subdivision stretches from Longlac Junction (Mile 0.0) near Longlac, Ontario, to Current Junction (Mile 195.5), Current River, Ontario, and was opened for traffic in 1915.

The track consisted of 39-foot jointed 100-pound rail rolled and laid in 1952. The ties were softwood installed about 3,040 per mile with rail anchors spaced at an average of 12 to 14 per rail. There were four spikes per tie with double-shouldered tie plates. Ballast was crushed rock, renewed in 1982. The track condition in the derailment area was good. The authorized maximum train speed in the area of the accident was 35 mph.

1.8 Occurrence Site Information

The derailment occurred on a section of track which runs parallel and in proximity to the eastern shoreline of Lake Nipigon. At this location, the railway track is essentially orientated in a north/south direction. The soil slopes above the track to the east were steep. The roadbed had been constructed on 18-inch ballast over in situ silty deposits.

The track was approximately 25 feet above the lake surface. Large rocks were located at the base of the roadbed to minimize erosion from the lake wave action and to assist in maintaining a stable slope.

A large amount of subgrade material had been displaced both to the south and west into Lake Nipigon. This displacement of material had created a large cavernous depression measuring about 20 feet wide by 75 feet long by 20 feet deep in the subgrade at the occurrence site. The walls of the cavern were vertical or overhanging and the top boundaries were jagged.

A creek, approximately 75 feet to the north of the depression, drained water from high ground to the east of the track into the lake through a 36-inch-diameter culvert under the roadbed. A drainage ditch of variable depth and width extended along the eastern side of the roadbed both north and south of the depression. At the culvert, the ditch was approximately seven feet below track level. Just south of the depression, the ditch emptied into a large basin, approximately 10 feet deep in places, abutting the east-side roadbed.

At the time of the derailment, a layer of ice was located in the drainage ditch to the north of the depression. The surface of this ice was noted to be above the top of the culvert and approximately one foot below the roadbed surface. This ice was also seen at the area abutting the most northerly extremes of the depression shortly after the occurrence. The ice was of sufficient thickness for a first responder to walk on it while attempting to aid in the removal of one crew member from the cab. It was noticed that water was flowing from the north over the surface of the ice into the depression. In order to stop this flow, a tie was placed over the ice at right angles to the track. The next day, this ice had mostly melted.

The two locomotives were within the depression. The top of the cab of the lead locomotive was slightly below the original level of the track. Most of the 15 derailed cars were turned sideways and five had rolled down the grade on the lake side. Most of the derailed cars had burst open, losing their contents (newsprint).

On the day of the occurrence, water was found to be flowing through the culvert; however, the exposed downstream end of the culvert (west end) exhibited a large plug of ice which occupied approximately 3/4 of the cross-sectional area of the passage. Water was flowing through an arc-shaped gap between the bottom of the ice plug and the bottom of the culvert. The water flowed underneath a thick, continuous layer of ice, down the slope into Lake Nipigon. The surface of the lake adjacent to the shore at this location was frozen.

CN officials indicated that this area above the depression had not historically been known to exhibit track subsidence or other problems related to poor subgrade; however, in the area to the north of the depression and above the culvert, the track had been recently shimmed and the rails were laterally supported due to subsidence of the roadbed.

When viewed from directly above, the depression resembled a large, curved trench which diagonally crossed the railway track in a general northeast to southwest direction. The trench-like feature was closed at the northeast end and open at the southwest end. In top view, the northeast end of the trench was relatively pointed towards the ditch which led to the culvert and stream.

In side view, the northern end of the trench exhibited a cave-like undercut, extending out underneath the track. The trench gradually dropped in elevation and widened as it was traversed from the northeast end towards the open southwest end. The southwest end opened up onto Lake Nipigon.

Subgrade material had flowed in a fluid-like manner along the length of the trench, out onto the frozen surface of the lake. The general shape of the deposits resembled a fan which was about 25 metres by 75 metres in size and about 2 metres deep near the depression. The saturated subgrade material appeared to have been released suddenly but may also have partly been propelled onto the ice by the rapid compression of the locomotives falling into the depression.

Water flowing over the fan of slumped material after the occurrence had left a number of small rivulets in an east to west direction and then lay on the surface of the ice about the fan.

To the south of the depression and opposite the 10-foot-deep basin east of the track, the westerly subgrade slope had given way and surface material had slumped towards the lake. The slope material in this area was found to be very loose and water-saturated and gave under foot the day after the occurrence.

1.9 Method of Train Control

Train movements on the Kinghorn Subdivision are governed by the Occupancy Control System (OCS) authorized by the Canadian Rail Operating Rules and supervised by a rail traffic controller (RTC) located in Winnipeg, Manitoba.

1.10 Weather

The temperature was approximately eight degrees Celsius, and there was no wind or precipitation.

A review of meteorological records for the area revealed that, from 06 April 1994 to 28 April 1994, daytime high temperatures were at a low of two degrees Celsius and nighttime low temperatures were all below the freezing point. The four days before the accident, the maximum daytime temperatures averaged 10.8 degrees Celsius and the nighttime low averaged minus 5 degrees Celsius.

The snow cover in the region was below seasonal averages, ranging from 10 to 20 centimetres in mid-April. Ten and one half centimetres of fresh snow was recorded on 16 April 1994 and one millimetre of rainfall was experienced on 23 April 1994.

1.11 Recorded Information

The event recorder data revealed that seven seconds elapsed from the time the train brakes were placed in emergency (at approximately 34 mph) until the locomotives stopped suddenly, while still travelling at about 26 mph.

Monitored train operating systems were functioning as intended.

1.12 Local Geology and Water Flow

1.12.1 General Observations

The derailment site was in an area of varied glaciolacustrine silts and clays formed during the deglaciation of the area and showed some disturbance due to slumping which occurred at the time of deposition.

The area from Mile 89.5 to Mile 91.0 was known to have local cave-ins and collapse with sporadic rockfall and the development of talus slopes. Features local to the occurrence site were fresh-looking bank slips that approach the railway grade, conical-shaped collapse holes and differentially settled, deformed and faulted clay bands.

The size and composition of the deposit at Mile 89.7 were such that water could move within it at a rate of about three feet in 10 days. The material that originally formed the depression and that flowed onto the lake surface, in a fan-like deposit, was water-saturated and highly fluid.

When the most northerly locomotive was removed from the depression, water was seen welling up through the "soup-like" mud at the bottom of that depression. The surface of that mud was estimated to be slightly above lake level. The depth of the mud is not known but it was more than a few inches. The length of time this water was flowing before the occurrence, or even if it was flowing before the occurrence, is not known. The source of that water is also unknown. The description of the water flowing through the mud is consistent with the movement of water under low head or pressure.

1.12.2 TSB Engineering Laboratory (LP64/94)

A soils expert from the Geological Survey of Canada, working with the TSB Engineering Laboratory, surveyed the accident scene. He determined that the geometry of the depression and deposits on the ice on Lake Nipigon suggested that the slumping of the subgrade was because of piping (also known as seepage or caving erosion). Piping was observed to be active at the site at the northern limit of the depression. The orientation of the depression indicated that water may have been diverted from a gully 75 feet to the north. Egress of water to Lake Nipigon is thought to have been prevented by the frozen ground. Because of the western exposure of the breached segment of the embankment, it is likely that the rate and magnitude of thaw of the frozen ground were greater at that location, thus allowing piping to take place. Evidence suggesting that the slumping was due to piping includes:

a) the fan-shaped deposits on the ice of frozen Lake Nipigon, indicative of the fact that the silt was deposited by a flow process;

b) the sharp, jagged boundaries of the depression;

c) the steep overhanging walls of the depression;

d) the elongated shape of the depression; and

e) the observation of piping at the site.

1.12.3 CN Geological Experts

CN geological experts suggest that the features indicative of the type and mechanism of the track bed failure are:

1) the non-plastic calcareous lacustrine silt bluff with clay bands and fine sand seams at and above the occurrence site;

2) a deep conical-shaped cave-in hole behind that bluff connected to a collapsed "blind" gully;

3) two gutter-like "sag" depressions overlying what are interpreted to be either open joints or stress-relief fissures oriented roughly parallel to the bluff;

4) the collapse phenomenon at the occurrence site is related to leaching of fine carbonate, mechanical removal of silt and fine sand particles and hydrocompaction from wetting;

5) as piping and hydrocompaction in the occurrence area are natural geological processes that have been going on for several thousand years, there had to be some extraordinary failure-initiating and triggering factor; and

6) the triggering factor must have been the increased ground-water flow in collapsible non-plastic to very slightly cohesive silty lacustrine sediment -- possibly enlarging or re-opening a pre-existing cavity or conduit, or creating sudden hydrocompaction and densification or an open, porous, and collapse-prone silty soil material.

The same geologists suggest that the triggering factor was extraordinary water infiltration possibly with restricted water escape due to frozen surface conditions and that the source of the water that precipitated the failure is speculative but could be:

1) artesian ground water under the subgrade;

2) increased surface run-off and infiltration of spring snowmelt over the entire surface of the lacustrine silt, including temporary ponding of run-off water in the bottom of a "blind" gully and possibly the connecting cave-in hole above the silt bluff; and

3) the migration of spring run-off water in the nearby creek into stress-relief fissures and joints immediately behind and parallel to the silt bluff.

Another possible factor was seen to be intermittent vibration (due to train traffic) of the loose, porous silt over a cavity created by past water migration through that material with a subsequent collapse of that cavity. There was, however, no hard evidence of such a cavity having existed.

1.13 Other Information

1.13.1 Other Train Crew Observations

Crew members of a southward train which passed through the area on 23 April 1994 noted that there appeared to be more water than usual on the east side of the track, but all seemed well and no soft track was noted. They did not interpret this condition as abnormal and made no report.

1.13.2 Culvert Inspections

A review of track inspection logs for the subdivision revealed that, on the period from 22 March 1994 to 25 April 1994, 11 culverts were found to be blocked and were cleared by maintenance-of-way forces.

The practice is to use a steam generator to make holes in the ice of a blocked culvert until water flows. If there is a flow of water through a culvert at inspection, no action is taken, irrespective of how low the flow rate.

1.13.3 Similar Accidents

1.13.3.1 CN Caramat Subdivision

In July 1992, a CN freight train encountered a collapsed subgrade at Mile 135.0 of the Caramat Subdivision near Nakina, Ontario. The train travelled onto the suspended portion of track and fell into a pond. Two crew members were killed and a third sustained serious injuries. The track bed failure was caused by a sudden draw down of water in the pond from a breached beaver dam. The roadbed had been built on a base of silt and peat at the turn of the century.

In July 1993, the Board recommended that the Department of Transport institute a collaborative program to identify other potential locations of incipient failure where main track has been laid over weak sediments or where waters adjacent to main track may be subject to rapid draw down (R93-04), and that restricted speeds be imposed for trains traversing those sites identified as most vulnerable to failure caused by draw down of adjacent waters (R93-05).

The Board also recommended that corrective measures be identified and implemented to increase soil stability with an acceptable factor of safety at those locations identified as being vulnerable to terrain slump (R93-06), and that the adequacy of current roadbed design criteria for laying roadbed over peat, silt, or other weak sediments be reviewed (R93-07).

Although the collapse of the roadbed on the Kinghorn Subdivision is not of an identical type as that on the Caramat Subdivision, the underlying cause (i.e., a railway built on weak sediments) was the same in both instances.

CN has undertaken certain corrective measures to alleviate the problem of beaver activity near rights-of-way, but little has apparently been accomplished, industry-wide, in response to soil weakness identification, bank stabilization or warning systems development.

In reaction to Board recommendation R93-07 concerning the design criteria for roadbed construction, the Minister of Transport has advised that future design and construction will be carried out in accordance with applicable engineering standards. However, there has been no indication that engineering standards have been improved or that they will be reassessed and found to be adequate for modern equipment and speeds.

1.13.3.2 CN Saint-Maurice Subdivision

In April 1993, a VIA Rail Inc. passenger train fell into a large gap in the roadbed after snowmelt run-off from a hillside backed up behind a frozen culvert and eroded the subgrade. Five members of the train crew and seven passengers were injured. In reaction to this accident, CN developed a "Spring Check List", issued system-wide on 14 March 1994, which among other requirements alerted both operating crews and maintenance-of-way forces to the need to:

- ensure that culverts are inspected for ice or debris before spring run-off; and

- watch for changing water levels, soft spots and potential slide areas and report promptly to the RTC.

2.0 Analysis

2.1 Introduction

The train was operated in accordance with company procedures and government safety standards. There was no indication that train handling was a causal factor and no evidence of equipment or rail defects were discovered. The crew could not bring the train to a stop before the cavernous depression in the track subgrade.

This analysis will therefore focus on the factors related to the creation of the cavernous depression below the track that resulted in the occurrence.

2.2 Consideration of the Facts

2.2.1 The Roadbed Collapse

The subgrade was part of a patchy distribution of glaciolacustrine silts and clays which are prone to slumping when saturated with water. The subgrade in the area of the depression was saturated with water before collapse onto the lake ice.

The area was experiencing spring-time snowmelt conditions and, although the snow cover was less than average, the daytime temperatures in the days before the accident were quite high.

A significant snowfall had also been experienced on 16 April 1994, which would have added to the run-off.

The nighttime below freezing temperatures were conducive to reduced run-off and increased freezing which in turn was conducive to the ice-plugging of culverts. Whether the culvert was blocked completely shortly before the occurrence is not known. However, as the culvert was 3/4 blocked shortly after the occurrence, it is a possibility.

The ice in the culvert to the north of the occurrence site was over the culvert inlet top and within one foot of the track level. It is clear that, at one time shortly before the occurrence, considerable water had accumulated in the ditch. The source of this water was mainly the stream to the north and east of the occurrence site flowing to the culvert. It is possible that water levels had never before reached to within one foot of the track in this area.

The water build-up in the ditch would only have been because the culvert was not capable of removing the water from the stream and the ditch. Such a build-up would have occurred if the culvert was blocked, but could have occurred even if there had been water flowing at a reduced rate through a partially blocked culvert.

The water in the ditch could have infiltrated the subgrade and may have resulted in an underground flow of water towards the main depression area, as is indicated as well by the geometry of the most northerly area of the depression. In addition, such water could have served to saturate the subgrade. In this respect, the recent track shimming above the culvert was a result of a softening of the subgrade about the culvert likely due to the infiltration of water from the ditch.

Given the elevation of the ice in the ditch, and that it would have been the elevation of water in the ditch at one time, that water may have migrated to the area to the south of the depression, a basin relatively large in area and depth. Surface water may have also entered this area from higher elevations to the east. There was no culvert to drain the water across the subgrade to the lake. At that point, the head of water would have been in excess of

10 feet. This could have also been a source of water that infiltrated the subgrade in the area of the main body of the depression.

Certainly, the collapse of surface material on the lake-side of the track, across from this catch basin, indicated that the subgrade abutting the catch basin was water-saturated.

Due to its western exposure, the western surface of the subgrade thawed quicker than the surrounding terrain. The localized thawing of the subgrade surface reduced its ability to withstand the pressure of the increasing height of subgrade that was water-saturated to the point where the fluidized subgrade flowed onto the surface of the lake.

2.2.2 Culvert Blockage

This accident has shown that, notwithstanding culvert surveillance as exercised by maintenance-of-way personnel on this subdivision and the emphasis of the requirement by railway management, blocked culverts can and do present on ongoing safety concern. The complete or even partial ice blockage of culverts can be followed by a build-up of water that can infiltrate certain types of subgrade rendering that subgrade unstable. It is also clear that wide daytime and nighttime temperature differentials can lead to conditions where the potential for such ice blockage is high.

2.2.3 Soil Conditions

Railway roadbeds constructed on clay and silt deposits before modern engineering requirements and techniques, in areas of actual or possible water-saturation conditions, present a potential safety risk to train operation. Constant monitoring of changes in site conditions and immediate reaction by railway personnel are required.

3.0 Conclusions

3.1 Findings

1. The train was operated in compliance with company procedures and government safety standards, and roadbed and track inspections were carried out as required.

2. Mild daytime temperatures followed by below freezing nighttime conditions resulted in the culvert north of the derailment site becoming partially blocked with ice.

3. The partially blocked culvert restricted the flow of the meltwater and resulted in the diversion and build-up of water, subgrade saturation to levels not previously experienced at this location, piping and the sudden displacement of the roadbed.

4. The roadbed had been constructed on glaciolacustrine silt and clay deposits which become unstable when saturated by water.

5. Current practices with respect to inspecting culverts do not take into account that, in certain circumstances, the flowing of water through a partially blocked culvert does not mean that water is adequately drained from about the subgrade.

3.2 Cause

Water infiltration of the subgrade of glaciolacustrine silts and clays resulted in the subgrade becoming saturated to a higher elevation than previously experienced and, as a result, it became unstable and slumped, leaving a large depression under the track. The water that infiltrated the subgrade originated from a build-up caused by a partially blocked culvert and possibly from underground low-pressure sources.

4.0 Safety Action

4.1 Action Taken

4.1.1 Train Speed Restrictions

CN has identified certain areas that present a potential threat for land and rock slides during spring run-off on the Kinghorn Subdivision. A train speed restriction of 10 mph will be in effect at these locations during spring run-off.

4.1.2 Water Management Program

A video about abnormal water conditions and effective interdepartmental communication of drainage problems and posters are now used as part of an awareness campaign for track maintenance employees, local supervisors, rail traffic controllers and train crews. CN is also developing a technical manual and a training video that will cover such topics as natural drainage systems, the composition of the roadbed, the unplugging of blocked culverts, nuisance beaver removal, the correct way to dismantle dams, and the controlled handling of water.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 20 April 1995.

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