Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A18Q0016

COLLISION WITH TERRAIN AT NIGHT

Robinson R44 Raven I (helicopter), C-GYMG
Saint-Joachim-de-Courval, Quebec
01 February 2018

Canada

ABOUT THIS INVESTIGATION REPORT

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

This report is the result of an investigation into a class 3 occurrence. For more information, see the Occurrence Classification Policy at www.tsb.gc.ca.

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Summary

On 01 February 2018, at about 1945 Eastern Standard Time, the privately operated Robinson R44 Raven I helicopter (registration C-GYMG, serial number 2081) departed Saint-Georges de Beauce, Quebec, with the pilot and 2 passengers on board, on a night visual flight rules flight to Saint-Alexis-de-Montcalm, Quebec. At 2032, the Canadian Mission Control Centre received a distress signal from the helicopter's emergency locator transmitter. At about 2135, the helicopter was found in a field in Saint-Joachim-de-Courval, Quebec, near Drummondville, Quebec. The helicopter was destroyed by impact forces and a post-impact fire. All of the occupants were fatally injured.

1.0 FACTUAL INFORMATION

1.1 History of the flight

On 01 February 2018, at 1419,[1] the privately operated Robinson R44 Raven I helicopter (registration C-GYMG, serial number 2081) departed Saint-Alexis-de-Montcalm, Quebec, with the pilot and 2 passengers on board for a flight to Saint-Georges de Beauce, Quebec, where they were to attend an open house at an educational institution. At around 1550, the pilot contacted the UNICOM[2] station at St-Georges Airport (CYSG) via radio and flew east over the airport toward the educational institution, where he landed at 1557. The pilot left the engine running, and, as soon as the 2 passengers had disembarked from the helicopter, he flew back to CYSG to refuel. After refuelling,[3] at 1631, the pilot flew back on his own to the educational institution, where he landed for the 2nd time at about 1640.

At 1909, the pilot called the person responsible for his flight following and indicated that he intended to depart soon and return to Saint-Alexis-de-Montcalm. At about 1945, the pilot departed with the 2 passengers on board.

At 2032, the Canadian Mission Control Centre (CMCC) received a distress signal from the helicopter's emergency locator transmitter (ELT).

At 2041, the Joint Rescue Coordination Centre (JRCC) in Trenton, Ontario, received from the CMCC the calculated location of the distress signal from C-GYMG's ELT. At 2106, the Sûreté du Québec (SQ) was notified by a resident of Saint-Joachim-de-Courval, Quebec, that an aircraft had crashed in his field and a fire had broken out. The municipal fire department and the SQ arrived on scene at about 2135. All of the helicopter occupants had been fatally injured.

1.2 Injuries to persons

Table 1. Injuries to persons

	Crew	Passengers	Others	Total
Fatal	1	2	–	3
Serious	0	0	–	0
Minor/None	0	0	–	0
Total	1	2	–	3

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1 All times are Eastern Standard Time (Coordinated Universal Time minus 5 hours).

2 UNICOM is a private air–ground radio communications facility at uncontrolled aerodromes.

3 According to the fuel transaction statement, 60.9 L of 100LL fuel were added.

1.3 Damage to aircraft

The front of the aircraft was completely destroyed, first by the impact forces, then by the resulting fire. The flight instrument panel, which had been ejected from the cabin at the moment of impact, was severely damaged. Most of the flight controls were consumed by the fire. The main mast and the rotor head were still attached to the gearbox, which appeared to have little damage. The blades of the main rotor and the tail rotor showed damage typical of an impact with an object while the blades are rotating. The tail boom was damaged but still attached to the fuselage.

1.4 Other damage

About 80 L of fuel was spilled following the impact.

1.5 Personnel information

Transport Canada (TC) records showed that the pilot held the necessary licence and qualifications for the flight, in accordance with existing regulations.

Table 1. Personnel information

Pilot licence	Private pilot licence - helicopter
Date of qualifying flight to obtain night rating*	25 October 2006
Medical expiry date	01 January 2019
Total flying hours	1130.6 (approximate)
Flight hours on type (R44)	217
Total night flying hours	56.2

* According to subsection 101.01(1) of the *Canadian Aviation Regulations*, "night" means the time between the end of evening civil twilight and the beginning of morning civil twilight. On 01 February 2018, evening civil twilight was at 1727 Eastern Standard Time.

The pilot had received his initial training on a Robinson R22 and held a private pilot licence – helicopter, issued in 2004, along with a valid Category 3 medical certificate. During his initial training to obtain a private pilot licence in 2004, he completed 5 hours of daytime dual-instrument flight. During the pilot's night rating training in 2006, he conducted 5 additional hours of instrument flight. Although the pilot had completed his night flight training in 2006, he did not receive his night flying qualification until July 2007, because of a delay in submitting his rating application to TC. He received an endorsement for the Robinson R44 on 17 September 2013. The pilot's personal flight log indicated that he had a total of 1127.5 helicopter flying hours[4] as at 21 January 2018. This included 56.2 hours of night flight, including 46.1 hours as pilot-in-command. Of these 46.1 hours, 20.4 were on the Robinson R44.

4 The number of flight hours on the day of the accident is estimated to have been 3.1 hours, bringing the total number of flight hours to approximately 1130.6.

The pilot had flown the same route twice before, in June 2017. However, those flights were during the day.

1.6 Aircraft information

1.6.1 General

Table 2. Aircraft information

Manufacturer	Robinson Helicopter Company
Type and model	R44 Raven I
Year of manufacture	2009
Serial number	2081
Certificate of airworthiness issue date	14 July 2010
Total airframe time (hours)	527.8 (approximate)
Engine type (number)	Avco-Lycoming O-540-F1B5 (1)
Propeller/rotor type (number)	Single twin-blade rotor (1)
Maximum allowable take-off weight	1088.2 kg
Recommended fuel type(s)	100LL
Fuel type used	100LL

The helicopter was imported into Canada in July 2010, at which time it was registered as C-GYMG. It was privately operated and was purchased in October 2014 by 9149-8055 Québec Inc., in which the pilot was a shareholder.

Records indicate that the helicopter was certified, equipped, and maintained in accordance with existing regulations. It had the equipment required for night flight as stipulated in section 605.16 of the *Canadian Aviation Regulations* (CARs). The helicopter was not equipped with a flight data recorder or a cockpit voice recorder, nor was it required to be by regulation.

As at 05 December 2017, the date of the last entry in the aircraft's technical logbook following a 50-hour inspection, the helicopter had accumulated a total of 521.3 hours of flying time since new. It had been flown an additional 3.4 hours after this inspection. With the daytime flights conducted on the day of the accident, estimated at 3.1 hours, the helicopter's total number of flying hours since new was approximately 527.8 hours.

The aircraft's weight and centre of gravity were within prescribed limits at the time of the accident.

Robinson Helicopter Company has delivered more than 12 000 helicopters; the majority of these are R44s. As at 13 August 2018, the Canadian Civil Aircraft Register showed

393 Robinson R44 helicopters operating in Canada, of which 237 were privately operated. There are 140 Robinson R44 helicopters in Quebec, 103 of which are privately operated.[5]

1.6.2 Emergency locator transmitter

The aircraft was equipped with a Kannad 406 AF ELT transmitting on 121.5 MHz and 406 MHz. The ELT was activated by the impact, but was subsequently destroyed by the post-impact fire. Only a part of its mounting bracket was found.

In this occurrence, the initial distress signal from the ELT installed on C-GYMG was received at 2032 by the CMCC on 406 MHz. At 2041, the calculated position[6] was transmitted to the JRCC, which is responsible for coordinating all search and rescue (SAR) operations for air and maritime emergencies in Canada. The approximate location of the wreckage was reported to the SQ at 2122.

The SQ located the wreckage and the occupants at 2135, about 60 minutes after the crash.

1.6.3 Registration of emergency locator transmitters

According to subsection 605.38(4) of the CARs, an ELT broadcasting on 406 MHz must be registered with the Canadian Beacon Registry, which is maintained by the National Search and Rescue Secretariat. The Registry stores information about personal locator beacons, emergency position indicating radio beacons (EPIRBs), and ELTs. Online access to the Registry is available to all owners of 406-MHz emergency beacons to register new emergency beacons or to update the required information. The information stored in the Registry includes the owner's name, aircraft details, and emergency contact information. SAR authorities cross-reference the emergency beacon identifier with the Registry and, with a single phone call, can determine whether the distress signal is a false alert or collect additional details to respond more effectively to the incident. Emergency beacon information can be added or updated online, or by faxing or emailing a completed registration form.

The use of ELTs transmitting on 406 MHz is now common throughout the aviation industry. According to the CMCC, it is common for the information in the Registry not to be updated after a change of ownership or registration. In this occurrence, the new owner had not updated the information in the registry after purchasing the aircraft in October 2014. As a

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5 In Canada, privately operated Robinson R44 helicopters represent 23.2% of all privately operated helicopters, or 237 out of a total of 1021 helicopters.

6 The CMCC normally allots 12 minutes to calculate the position before sending it to the JRCC. In this occurrence, the process took 9 minutes.

result, when the ELT was activated at the time of the impact, the information in the Registry led CMCC personnel to the former owner.

When this happens, the additional research required to track down the current owner can delay the deployment of SAR services.

1.7 Meteorological information

The weather data in this section was taken from a meteorological assessment[7] prepared by Environment and Climate Change Canada (ECCC) for the TSB as part of this investigation.

1.7.1 Summary

At 1900 on the evening of the accident, the centre of a low-pressure system was located north of Quebec and the system was tracking northeast at a speed of 15 to 20 knots. Associated with this system was a cold front extending to the U.S. and moving in a southeasterly direction at a speed of about 15 knots.

1.7.2 Weather forecasts

Graphical area forecasts (GFAs) are a tool available to pilots that shows the general upcoming weather conditions for a given geographic area.[8] On the day of the accident, the GFAs issued at 1242 and valid at 1900 (appendices A and B) provided the following weather forecasts for the area between the cold front and the north shore of the St. Lawrence River:

- Overcast sky at 3000 feet above sea level (ASL) with tops at 16 000 feet ASL;
- Intermittent visibility between 1 and 3 statute miles[9] (sm) in light snow;
- Occasional presence of towering cumulus conducive to snow showers, reducing visibility to ½ sm and ceilings to 600 feet above ground level (AGL);
- Southerly surface winds at 15 knots, gusting to 25 knots;
- Moderate mechanical turbulence possible from the surface to 3000 feet AGL;
- Moderate mixed icing possible between 3000 feet ASL and 10 000 feet ASL.

The forecasts for the Saint-Georges de Beauce sector and along the south shore of the St. Lawrence were as follows:

- Overcast at 3000 feet ASL with tops at 8000 feet ASL;
- Visibility of more than 6 sm;
- Locally, light snow could reduce visibility to 2 sm and ceilings to 1500 feet AGL;

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7 Environment and Climate Change Canada, *Meteorological Assessment February 2nd, 2018 St-Joachim-de-Courval, Quebec* (04 April 2018).

8 Graphical area forecasts are issued 4 times a day and are valid for 12 hours. Two charts are issued for each indicated period: one chart describes clouds and weather, and the other describes icing, turbulence, and freezing levels.

9 A statute mile is equivalent to 1.61 km.

- Moderate mechanical turbulence possible from the surface to 3000 feet AGL;
- Moderate mixed icing possible between 3000 feet ASL and 10 000 feet ASL.

Terminal aerodrome forecasts (TAFs), another tool available to pilots, provide information on the most likely weather conditions expected within a radius of 5 nm from the centre of the runway complex of a specific airport. On the day of the accident, the TAF for Trois-Rivières Airport (CYRQ) issued at 1439 forecast the following conditions as of 1900 that evening:

- Surface winds from 200° true (T) at 10 knots;
- Visibility of more than 6 sm in light snow;
- Broken cloud at 3000 feet AGL;
- Temporarily, between 1900 and 2200, visibility of 1 sm in light snow and with broken cloud at 800 feet AGL, and overcast at 2000 feet AGL.

1.7.3 Estimated weather conditions at the crash site

In order to determine what the weather conditions may have been at the time and place of the accident, the ECCC assessment was based on information from the Villeroy weather radar, which was located about 50 sm northeast, and on the observations recorded at the following weather stations located closest to the accident site:

- Saint-Germain-de-Grantham (MSI) (about 12 sm south-southeast);
- Nicolet (WNQ) (about 15 sm north);
- Trois-Rivières Airport (CYRQ) (about 32 sm north);
- Lemieux (MLU) (about 32 sm northeast); and
- L'Assomption (WEW) (about 39 sm west-southwest).

Surface winds in front of the band of precipitation were predominantly from the south, between 10 and 20 knots. Between 1945 and 2015, winds shifted to be from the northwest, with wind speed increasing to around 20 knots, gusting to 30 knots, and causing moderate turbulence. The area of precipitation ahead of the front covered the Saint-Joachim-de-Courval sector, and the estimated snowfall rate was 1.5 cm/h to 2 cm/h[10] (Appendix C). The drop in temperature resulting from the approaching cold front lowered the freezing level, which had initially been at 2200 feet ASL. According to the ECCC assessment, it is possible that precipitation began as rain and/or snow pellets before changing to snow. Both the freezing level and the change in type of precipitation represent a significant icing risk.

The moisture profile of the surface at 9000 feet ASL was light and the air mass was unstable, which was favourable to the development of towering cumulus. The presence of towering cumulus is often associated with heavy precipitation and turbulence.

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10 These snowfall rates correspond to estimated surface visibilities of ¾ sm and ½ sm, respectively.

1.8 Communications

No transmission from the pilot was captured in the area of the occurrence. No distress message from C-GYMG was heard or recorded on the 121.5 MHz emergency frequency.

1.9 Flight recorders

The aircraft was not equipped with a flight data recorder or a cockpit voice recorder, nor were these required by regulation.

The pilot used an application called ForeFlight[11] on a tablet for navigation and had an active ForeFlight account. When activated by the pilot, the application can log certain flight data (such as speed, altitude, and itinerary) by using the global positioning system (GPS) function of the mobile device. An online account is also created and stores information from previous flights (if this option is activated). The account can be accessed from any computer. Data are normally recorded on the mobile device's internal memory and transferred to the online account when the device is connected to Wi-Fi or, in some cases, to a cellular network.

In this occurrence, the data for the return flight were not logged to the account, but were probably still on the tablet's internal memory at the time of the accident. However, the tablet was too severely damaged by the impact forces for TSB laboratory specialists to recover the data. Data for the flight from Saint-Alexis-de-Montcalm to Saint-Georges de Beauce that were recorded on the ForeFlight account indicated that this flight took place at an average altitude of 850 feet AGL.

The Montréal Area Control Centre indicated that no aircraft were observed within the radar coverage area for the sector between Saint-Joachim-de-Courval and Saint-Georges de Beauce between 2000 and 2045. The helicopter therefore conducted this flight below the radar coverage altitude. Near Saint-Georges de Beauce, this altitude corresponds to about 5000 feet, and, near the accident site, to about 1800 feet. It was therefore not possible to determine the helicopter's flight altitude.

1.10 Wreckage and impact information

1.10.1 General

The impact marks on the ground indicated that the impact angle was about 25° downward on a trajectory of 9° magnetic (M). The aircraft then bounced for 13 m before coming to rest on its right side, approximately 180° from the impact trajectory. The tail rotor gearbox, the tail fin, the skids, plastic parts from the windshield and side windows, and door panels were found at the beginning of the impact trajectory.

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11 ForeFlight Intelligent Apps for Pilots.

The front part of the fuselage located forward of the firewall had been destroyed by fire. The circuit breaker panel was not found, and the instrument panel, which was severely damaged, was found near the aircraft but outside of the fire zone. The removable left-side flight controls were not installed at the time of the impact.

1.10.2 Wreckage examination

The wreckage was transported to the TSB Engineering Laboratory in Ottawa, Ontario, for detailed examination.

The recovered flight instruments were examined (Appendix D). Although all of the instruments had impact damage, it was still possible to determine that they were indicating an attitude of 25° of forward pitch and an 81° roll to the right at the time of impact. The airspeed indicator read approximately 80 knots, and the vertical airspeed indicator read 1750 fpm.

The damage to the aircraft was also consistent with a forward-pitch impact with a pronounced right roll.

The flight controls that had not been consumed by the post-impact fire indicated multiple overload failures; however, it was still possible to establish the continuity of the available components.

The Telatemp[12] indicator strip attached to the upper bearing on the belt tensioner showed no sign of discoloration, which eliminated the possibility that the bearing had overheated before the accident.

The nature of the damage to the main rotor and the tail rotor indicates that they were turning and being powered by the engine at the time of the impact.

An examination of the engine and its accessories revealed rotational marks on the cooling fan. The engine controls were in a position indicating that the engine was running. No anomalies that may have hindered engine operation were found.

In order to corroborate the observations made during the engine examination, the bulbs of the warning lights were examined to determine whether an indicator light could have been illuminated and required the pilot's attention.

The Robinson R44 Raven I has 13 warning lights that alert the pilot to conditions requiring attention. Eight are at the top of the dashboard, and 5 are on the centre panel (Figure 1).[13]

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12 Telatemp temperature indicator strips are attached to specific components; in this case, one was attached to the freewheel unit. Each strip contains boxes that turn black permanently if the temperature of the component is higher than normal.

13 The exact configuration of the dashboard may vary according to the aircraft's optional equipment and year of construction.

Figure 1. Typical dashboard in a Robinson R44 Raven I

Light bulb filaments will usually deform (lengthen or stretch) if they are hot or incandescent at the time of impact. Filaments can break apart when cold, or they may not show any change.

In this occurrence, only 3 bulbs had intact glass enclosures and showed distinct signs of being off at the time of impact: the MR TEMP (main rotor temperature), ROTOR BRAKE, and CARBON MONOXIDE bulbs. All other bulbs showed signs of damage to the glass enclosure and had fractured filaments; their status at the time of impact could not be determined with certainty (Appendix E).

Although the status of some of the indicator lights at the time of impact cannot be determined with certainty, other elements indicate that they were most likely off. For example, it is unlikely that the LOW FUEL indicator was on, given the amount of fuel on board before the helicopter departed for Saint-Georges de Beauce and the amount of flight time. Examination of the components of the other indicators did not reveal any anomalies that would suggest that they were activated before the impact.

The aircraft was equipped with a GPSMAP navigation device manufactured by Garmin Ltd. The flight data recording mode had not been activated, so no data related to this occurrence could be recovered.

All of the aircraft mechanical components found were examined, and none showed signs that a mechanical failure might have contributed to the accident.

1.11 Medical and pathological information

There is no indication that the pilot's performance was affected by physiological factors.

1.12 Fire

Unconfined fuel is the combustible material that plays the most significant role in small-aircraft accidents. Although the occurrence aircraft had been equipped with factory-installed flexible fuel tanks when it was manufactured in 2009, fire consumed most of the cabin following the impact. The main fuel tank was not found; the auxiliary tank was found near the wreckage. The filler cap was still in place, and the auxiliary tank contained a small amount of fuel. The fuel tank outlet pipe had been ruptured by the impact forces.

A fuel sample was taken and tested. The fuel did not contain any water or contaminants, and its colour indicated that it was 100LL fuel, which was appropriate for the engine of this aircraft.

1.13 Survivability

Survivability was low, given the forces exerted on the cabin structure at the time of impact and the intensity of the resulting fire.

1.14 Tests and research

1.14.1 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP027/2018 – Light Bulb Analysis
- LP033/2018 – Wreckage Examination
- LP034/2018 – Instrument Examination
- LP093/2018 – Impact Analysis

1.15 Additional information

1.15.1 Night flight

1.15.1.1 General

Night visual flight rules (VFR) flights expose pilots to higher accident risks due to phenomena and characteristics that are specific to this type of flight. The lack of visual cues and the various associated illusions may lead to spatial disorientation. If pilots do not quickly detect and control this spatial disorientation, they can rapidly lose control of the aircraft.

1.15.1.2 Night vision

The visual performance of the human eye is drastically reduced in low-light situations. Even when conditions for a night VFR flight are ideal, including good celestial light, the pilot's visual acuity[14] may degrade to 20/200 or less. This means that a person can see at 20 feet what he or she would normally be able to see at 200 feet in daylight.[15]

It takes an average of 30 minutes for the human eye to adapt to a low-light environment. Night vision is reduced during this adaptation period, and any bright light can compromise this adaptation. For this reason, pilots are advised to keep dashboard illumination at a low setting and to avoid exposure to bright lights just before takeoff. Another factor affecting adaptation to low-light environments is reflections from the cabin lights off the windshield, which can make it harder for pilots to see during flight.

In this occurrence, the pilot had a practice of navigating with his tablet mounted in front of him. Because the tablet was extensively damaged in the accident, it could not be determined whether the tablet was operating at the time of the accident. It was therefore not possible to determine the brightness level in the cockpit and whether it could have affected the pilot's night vision.

1.15.1.3 Spatial disorientation

Humans have the ability to discern the orientation of their body (lying down, standing, leaning, etc.) when they are in physical contact with the ground. Humans are not accustomed to the 3-dimensional environment of flight, and conflicts may arise between the senses and illusions that make it difficult or impossible to maintain spatial orientation. Spatial disorientation is defined as the "inability of a pilot to correctly interpret aircraft attitude, altitude or airspeed in relation to the Earth or other points of reference."[16]

Humans process information from 3 sensory systems to orient themselves in space:

- the visual system,
- the vestibular system (information from the inner ear), and
- the proprioceptive system (information from muscles, joints, and bones).

The visual system provides 80% of the information used for spatial orientation. If visual information is lost, all that remains is the 20% of information that comes from the vestibular and proprioceptive systems. The information from these 2 systems is less precise and more susceptible to error, because they are prone to illusions and misinterpretation.

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14 Visual acuity refers to the clarity of vision.

15 United States Department of Transportation, Federal Aviation Administration, *Pilot's Handbook of Aeronautical Knowledge* (Oklahoma, 2016), p. 17-21.

16 Australian Transport Safety Bureau, ATSB Transport Safety Investigation Report – Aviation Research and Analysis Report B2007/0063: An overview of spatial disorientation as a factor in aviation accidents and incidents, (Canberra City, Australia, 2007), p. vii.

When visual cues from the ground are poor or non-existent, spatial disorientation can be overcome by switching to instrument flight.

To avoid a loss of control, pilots must be familiar with the mechanisms that lead to spatial disorientation, be aware of the potential for disorientation when visibility and ground references are reduced, and understand how to handle such a situation.

The phenomenon of spatial disorientation and its consequences have been documented. For example, in TSB Aviation Investigation Report A11Q0168, on a collision with terrain following a takeoff at night by a Robinson R44 Raven II in Saint-Ferdinand, Quebec, on 27 August 2011, the pilot conducted a night flight with few outside visual references to the ground and likely lost control of the aircraft shortly after takeoff because of spatial disorientation.

1.15.1.4 Deterioration of weather conditions

Unlike on day VFR flights, weather phenomena are difficult to observe at night because of the low light conditions. It is therefore likely that pilots departing in weather conditions that are favourable for night VFR flight would be unable to observe a deterioration in weather conditions and take the necessary measures before inadvertently entering instrument meteorological conditions (IMC).[17]

To reduce the risks of encountering IMC, pilots should have all of the relevant information for making an informed decision about whether to take off or delay the flight. The CARs state that the pilot-in-command of an aircraft must "be familiar with the available weather information that is appropriate to the intended flight."[18]

In this occurrence, the weather data available to the pilot forecasted weather conditions at certain locations between Saint-Georges de Beauce and Saint-Alexis-de-Montcalm that were below the minima required by the CARs for night VFR flight (see section 1.15.2, Regulatory requirements for night flight). The pilot did not contact the flight service station (FSS) for information on the weather conditions along the flight path, but he may have found out the weather conditions via other means, such as on the internet. However, it could not be determined whether the pilot had used the internet to obtain weather information. Consequently, it could not be determined whether he was aware of the weather conditions forecast along the flight path.

When precipitation appears on the flight path, it reduces the horizontal and vertical visibility. When it snows, vertical visibility can be significantly lower than the visibility forecasted for the surface, below the cloud base. Surface visibility is a measurement of

17 "Meteorological conditions less than the minima specified […], expressed in terms of visibility and distance from cloud [for VFR flight in the *Canadian Aviation Regulations*]." (Source: Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 101.01).

18 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, section 602.72.

horizontal visibility near the surface of the Earth and differs from the visibility from the cockpit when pilots are looking at the ground during a flight (the slant visual range). Furthermore, at night, there may be only isolated lights from a few buildings, and the intensity of those lights may diminish rapidly with altitude.

Aircraft accidents resulting from flights that depart under visual meteorological conditions (VMC) and continue until the pilot loses visual reference with the ground end in either a loss of control or a controlled flight into terrain. Data gathered by the TSB for various types of airplane and helicopter accidents that occurred from 2000 to 2014 show that this accident type resulted in the greatest number of fatalities for all accident types in this period. In these accidents, 74 people died (47 fatalities in airplane accidents and 27 fatalities in helicopter accidents).

The collected data lead to the observation that the total flight experience of pilots is not preventing this type of accident from occurring. For helicopter pilots involved in accidents caused by a loss of visual reference followed by a loss of control in flight, the average total number of flight hours was 2617 hours. For pilots involved in controlled flight into terrain accidents, the average total number of flight hours was 6837 hours.

In 2013, the Australian Transport Safety Bureau (ATSB) published a study on accidents that occurred during night VFR flights over a 20-year period.[19] The pilots involved in these accidents had different types of licences and qualifications, and varied levels of experience. Two thirds of the pilots had an aeroplane type rating, and one third had a helicopter type rating. Almost all of the accidents included in the study occurred in dark night conditions.[20]

1.15.2 Regulatory requirements for night flight

According to the CARs, pilots in VFR flight within or outside controlled airspace must operate their aircraft with visual reference to the surface, during the day and at night.[21] The CARs define a surface as "any ground or water, including the frozen surface thereof."[22]

In addition to the visual cues required for night VFR flight in a helicopter in uncontrolled airspace, the following conditions must be met:

- In-flight visibility must be at least 3 miles.
- If the helicopter is operated at or above 1000 feet AGL and above, its distance from the clouds must be not less than 500 feet vertically and 2000 feet horizontally.
- If the helicopter is operated at less than 1000 feet AGL, it must stay clear of cloud.[23]

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19 Australian Transport Safety Bureau, AR-2012-122, *Avoidable Accidents No. 7: Visual flight at night accidents: What you can't see can still hurt you* (17 December 2013).

20 A dark night has a moonless and/or overcast sky.

21 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraphs 602.114(a) and 602.115(a).

22 Ibid., section 101.01.

23 Ibid., section 602.115.

Thus, according to the TC interpretation of night VFR flight requirements, a flight over an area without artificial lighting and without sufficient ambient lighting for the pilot to see the horizon clearly (i.e., sufficient to fly only with reference to the surface) would not meet the requirements for VFR flight. Rather, this flight would meet the requirements of an instrument flight rules (IFR) flight, in which pilots use flight instruments to operate the aircraft safely.

Following the TSB investigation[24] into a helicopter crash where the flight had departed under night VFR from a remote airport with insufficient runway lighting, the TSB raised concerns with the lack of clarity in the practical meaning of the definition of a "flight with visual reference to the surface." The Board recommended that

> the Department of Transport amend the regulations to clearly define the visual references (including lighting considerations and/or alternate means) required to reduce the risks associated with night visual flight rules flight.
>
> **TSB Recommendation A16-08**

In September 2016, TC responded as follows to Recommendation A16-08:

> Transport Canada agrees with this recommendation.
>
> TC will address this recommendation in two steps; first with safety promotion and education activities as early as fall 2016; and secondly, by initiating a regulatory amendment project in 2017 including consultation with our key stakeholders. Safety promotion and education will leverage TC's recently published Advisory Circular No. 603-001 — Use of Night Vision Imaging Systems.

The TSB assessment of TC's response in December 2016 was as follows:

> In its response, TC indicated that it will take a two-fold approach to address this recommendation to reduce the risks associated with night visual flight rules flights. In the short term, TC will conduct safety promotion/education activities, which will be followed in 2017 by a regulatory amendment project. The Board is pleased that TC is taking action to address this safety deficiency.
>
> However, until specific details about the proposed regulatory changes are fully known, the TSB cannot evaluate if these actions will fully address the safety deficiency associated with visual flight rules flights.
>
> Therefore, the response to Recommendation A16-08 is assessed as **Satisfactory Intent**.

Since May 2013, the TSB has investigated 2 other fatal accidents involving private aircraft on night VFR flights. The investigation reports highlighted the lack of clarity in the regulations regarding visual references.[25]

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24 TSB Aviation Investigation Report A13H0001.

25 TSB aviation investigation reports A15O0188 and A17O0209.

1.15.3 Safety notice issued by Robinson Helicopter Company

Robinson Helicopter Company has issued 2 safety notices warning pilots of the risks of night flight in marginal weather conditions.[26,27] The company stresses that pilots must never fly at night unless they have clear weather with unlimited or very high ceilings and plenty of celestial or ground lighting to maintain good visual reference to the ground. If pilots lose visual references, there is an increased risk that they will quickly lose control of the helicopter.

Helicopters have less inherent stability than airplanes and have much higher roll rates. When a pilot loses all visual references and experiences the effects of spatial disorientation, any incorrect control inputs can result in a loss of control if the pilot does not quickly take corrective action by using his or her instrument flight skills. The Robinson R44 Pilot's Operating Handbook notes that VFR operation at night requires "visual reference to ground objects illuminated solely by lights on the ground or adequate celestial illumination."[28]

The topography around the accident site consisted largely of snow-covered farmland and a few houses along the Saint-François River, about ½ sm southwest of the accident site (Figure 2). There were few visual references to the surface that were illuminated by ground lighting. The sky was overcast at the time of the accident, so it is presumed that the celestial lighting was inadequate.

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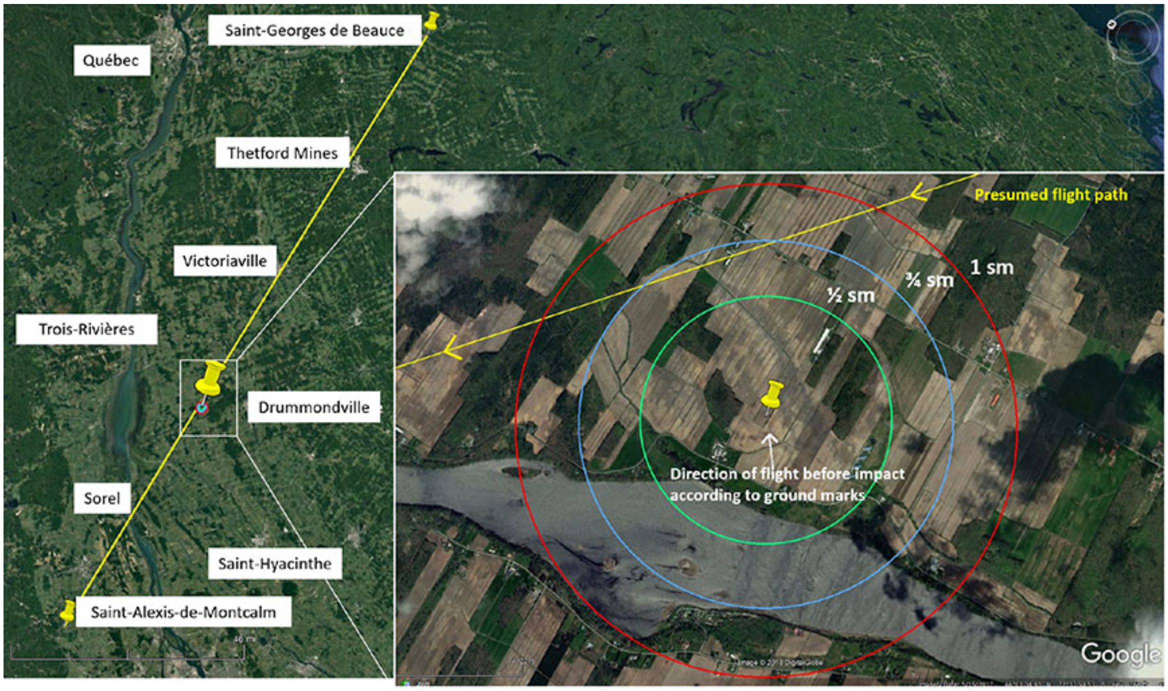
26 Robinson Helicopter Company, Safety Notice SN-18, *Loss of Visibility Can Be Fatal* (June 1994).

27 Robinson Helicopter Company, Safety Notice SN-26, *Night Flight Plus Bad Weather Can Be Deadly* (June 1994).

28 Robinson Helicopter Company, *R44 Pilot's Operating Handbook and FAA Approved Rotorcraft Flight Manual*, RTR 461 (21 October 2016), Section 2: Limitations, p. 2-6.

Figure 2. Presumed flight path of the occurrence aircraft, with inset showing the presumed visibility (represented by circles) at the time of the occurrence, and the direction of flight prior to impact, based on ground markings (Source: Google Earth, with TSB annotations)



1.15.4 Night flight training

Standard 421.42 of the CARs states the following with regard to the experience required to apply for a night rating:

> **(2) Private Pilot Licence - Helicopter**
>
> (a) **Experience**
>
> An applicant for a night rating shall have acquired in helicopters a minimum of 20 hours of pilot flight time which shall include a minimum of:
>
> (i) 10 hours of night flight time including a minimum of:
>
> (A) 5 hours dual flight time, including 2 hours of cross-country flight time,
>
> (B) 5 hours solo flight time, including 10 take-offs, circuits and landings, and
>
> (ii) 10 hours dual instrument time.
>
> (iii) Credit for a maximum of 5 hours of the 10 hours of dual instrument time may be given for instrument ground time, provided the total instrument time is in addition to the 10 hours night flight time in subparagraph (a)(i) above.[29]

A pilot can therefore complete 5 hours of flight time on a simulator, 5 hours of daytime dual instrument flight with a visor (used to limit vision surrounding the navigation instruments),

29 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, Standard 421.42(2)(a).

and only 10 hours of actual night flight before sending his or her application for a night rating to TC.

No in-flight testing is required by regulation for pilots to obtain a night rating. Only a qualification flight and the minimum number of flight hours indicated above are required. The CARs do not define what constitutes a qualification flight. However, TC considers the qualification flight to be the last dual instrument flight of night flight training.

The regulations in effect at the time of the accident did not require theoretical ground training on considerations specific to night flight (such as spatial disorientation, optical and sensory illusions, night vision, human factors, pilot decision making, and fatigue) to obtain a night rating. The choice of subjects to cover is at the discretion of the instructor. The investigation was unable to determine whether the pilot had taken theoretical training during his night flight training or what subjects would have been covered, because the archives of the organization that delivered the pilot's night flight training were destroyed by fire in January 2010.

The instructor is the person who certifies that the applicant is competent for night flying. However, the notion of competency is not defined by specific criteria in the regulations.

Although the night rating requirements of the CARs are the same for pilots who have a private aeroplane licence and pilots who have a private helicopter licence, Standard 421.42(1) requires applicants with a private aeroplane licence to demonstrate the "level of skill specified in the *Flight Instructor Guide - Aeroplane* (TP 975),"[30] which states the following in Exercise 25 – Night Flying:

> There is no flight test required for the night rating, but the instructor is expected to know when the student is competent to exercise the privileges of the rating, which is more than simply acquiring the necessary dual and solo flight time. The student should be able to meet, for those exercises covered in night flying, the same standard set out in the Flight Test Standards, Private and Commercial Pilot Licences — Aeroplane (TP 2655E).[31]

However, TP 2655 has not been in effect since 01 September 2001, and instructors can no longer refer to it. TP 2655 has been replaced by 2 other documents that no longer refer to Exercise 25 – Night Flying.[32,33] The latest revision of TP 975 has been in effect since September 2004 and has not been updated since then.

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30 Ibid., Standard 421.42(1)(b).

31 Transport Canada, TP 975, *Flight Instructor Guide* (revised September 2004), p. 172.

32 Transport Canada, TP 13462, *Flight Test Guide—Commercial Pilot Licence—Aeroplane*, Fourth Edition (April 2016).

33 Transport Canada, TP 13723, *Flight Test Guide—Private Pilot Licence—Aeroplane*, Fourth Edition (April 2016).

Standard 421.42(2) does not require applicants who have a private helicopter licence to demonstrate a specific level of competency in any of the guides developed by TC on personnel training and licence issuance.

Once applicants have completed their training, they have up to 12 months following the date of their qualification flight to submit their night rating application to TC. After 12 months, applicants are no longer considered competent and must repeat the qualification flight. The pilot in this occurrence had sent his application to TC 9 months after his qualification flight. Although TC does not usually receive an application so long after the training was completed, it was within the maximum time frame prescribed by the regulations; therefore, the rating application was accepted.

1.15.5 Recency requirements

Subsection 401.05(2) of the CARs states that

> no holder of a flight crew permit or licence, other than the holder of a flight engineer licence, shall exercise the privileges of the permit or licence in an aircraft unless the holder
>
> (a) has successfully completed a recurrent training program in accordance with the personnel licensing standards within the 24 months preceding the flight; and
>
> (b) where a passenger other than a flight test examiner designated by the Minister is carried on board the aircraft, has completed, within the six months preceding the flight,
>
> (i) in the case of an aircraft other than a glider or a balloon, in the same category and class of aircraft as the aircraft, or in a Level B, C or D simulator of the same category and class as the aircraft, at least
>
> (A) five night or day take-offs and five night or day landings, if the flight is conducted wholly by day, or
>
> (B) five night take-offs and five night landings, if the flight is conducted wholly or partly by night [...].[34]

Recurrent training measures that are considered acceptable according to Standard 421.05 of the CARs are presented in the table in Appendix F of this report.

Pilots are required to record their recurrent training in their personal logbook.[35] The occurrence pilot's personal logbook did not mention any review of theoretical knowledge, and it indicated that the pilot's last dual instrument flight with a qualified instructor was in September 2013. Over the last 6 months, the pilot had flown 3.2 hours of night flight as pilot-in-command, and the last night flight took place on 09 September 2017. However, the

[34] Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, subsection 401.05(2).

[35] Ibid., subsection 401.08(1).

pilot's personal logbook did not confirm whether the number of landings and takeoffs met the CARs requirements for transporting passengers.

The ATSB study on accidents during night VFR flight explains how the right strategies can significantly reduce the risks associated with night VFR flight. One of the proposed strategies is for pilots to be current, proficient, and disciplined with regard to instrument flight, and to avoid flying in conditions that exceed their capabilities.[36]

The CARs do not require pilots with a night rating to undergo recurrent theoretical and practical reviews on instrument flights and topics specifically related to night flying. It is therefore up to pilots to maintain their skills based on the type of flying they do. TC does not monitor recency requirements for private pilot licences or recreational pilot permits.

In comparison, since the 1970s the U.S. Federal Aviation Association (FAA) has required all pilots who act as pilot-in-command to undergo, every 2 years, a minimum of 1 hour of flight training and 1 hour of ground training with a qualified instructor, in accordance with the requirements of the U.S. *Federal Aviation Regulations* (FAR).[37] The instructor then certifies the pilots' recency training in their personal logbooks.

According to data provided by TC, there were 682 holders of a private pilot licence – helicopter in Canada in 2017. Of these, 295 were in Quebec. Of the 682 holders of a private pilot licence – helicopter, 121 had a night rating, and 80 of these were in Quebec. The number of private pilots with the privilege of flying at night is higher when including the 9602 holders of a private pilot licence – aeroplane who possess a night rating (out of a total of 21 150 pilots who held a private pilot licence – aeroplane in Canada in 2017).

1.15.6 Decision-making process

Decision making is defined as a human process that consists of gathering information, evaluating it, then acting on the basis of this evaluation. It is a complex cognitive process that allows one of several possible actions to be chosen. Once the chosen action has been performed, the decision-making process starts again, in order to validate whether the decision made corresponds to the best possible choice. Decision making is therefore a dynamic process.

Situational awareness is particularly important in making decisions. This awareness is characterized by the individual's perception of the environment, the manner in which information is processed so that the individual fully understands its meaning, and the projection of this information into the future. Inadequate or inaccurate situational

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36 Australian Transport Safety Bureau (ATSB), AR-2012-122, *Avoidable Accidents No. 7: Visual flight at night accidents: What you can't see can still hurt you* (17 December 2013).

37 Federal Aviation Administration, *Federal Aviation Regulations*, section 61.56: Flight Review.

awareness means that individuals are more likely to make mistakes by making an inappropriate decision.

Decision making is influenced by a number of cognitive mechanisms. Rather than identifying and then comparing and choosing from among the alternatives, Klein et al.[38] suggest that people in dynamic situations[39] use "naturalistic decision making." Pilots may recognize a situation based on similar past experiences and select a plan of action on the basis of a previous experience instead of the current situation. Without an in-depth evaluation, an inaccurate perception of the actual situation could lead to an ineffective decision because the decision was based on incorrect information.

Wickens and Hollands[40] suggest that, when making a decision, people tend to look for information that supports their initial assumption or decision, and will avoid or dismiss information that supports a different assumption or decision. Their studies have shown that people are often reluctant to change their decisions, even when confronted with evidence that suggests the decisions were wrong.

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38 G. A. Klein, J. Orasanu, R. Calderwood, and C. E. Zsambok (eds.), *Decision making in action: Models and methods* (Norwood, NJ: Ablex Publishing Corporation, 1993).

39 A dynamic situation means that the environment and conditions can change independently and as a result of the actions of the decision maker.

40 C. D. Wickens and J. G. Hollands, *Engineering Psychology and Human Performance*, third edition (Upper Saddle River, New Jersey: Prentice Hall, 2000).

2.0 ANALYSIS

2.1 General

The pilot had a valid licence and a night rating. However, the investigation could not confirm whether the pilot was permitted to exercise the privileges of transporting passengers on night flights. There is no indication that the pilot's capacities had been reduced by fatigue or physiological factors. An examination of the wreckage and the aircraft's technical records did not reveal any mechanical problems that could have played a role in the occurrence before or at the time of the accident.

The rotation signatures present on the engine cooling fan and the nature of the damage to the main rotor and tail rotor indicate that they were operating normally at the time of impact.

An examination of the instruments combined with the impact dynamic analysis indicate that the aircraft was in a forward pitch attitude and a pronounced right roll at the time of impact. This abnormal flight attitude is likely the result of a loss of control due to spatial disorientation.

The analysis will therefore focus on a possible scenario involving the pilot's spatial disorientation, limited night visual flight rules (VFR) flight experience, recency of skills, and decision making.

2.2 Spatial disorientation

After analyzing the weather conditions present in the Saint-Joachim-de-Courval area at the time of the accident, the investigation determined that the surface visibility would have been no more than 1 statute mile (sm) in snow showers. It is very likely that the slant visual range was less than 1 sm. In addition, the risk of frost noted in the weather forecasts meant there was a risk of a layer of frost covering the helicopter's windshield and thus further reducing visibility during flight.

Robinson Helicopter Company issued 2 safety notices highlighting the importance of flying at night only in clear weather, with unlimited or very high ceilings, and with plenty of celestial or ground lighting for reference. In this occurrence, visibility was reduced by snow showers, celestial illumination was likely inadequate due to the cloud cover, and visual references on the ground were limited to a few nearby buildings. Consequently, it is highly likely that the pilot encountered unfavourable weather conditions that resulted in a loss of visual references to the ground.

The weather forecasts included moderate turbulence between the surface and 3000 feet above ground level (AGL), which would make flying more unstable and require more correction inputs by the pilot to maintain straight and level flight. In addition, because of the inherent instability of this type of aircraft, if a pilot experiences spatial disorientation, an incorrect control input will result in a loss of control if the pilot does not quickly take corrective action by relying on his or her instrument flight skills. This type of situation, combined with moderate turbulence, severely hinders a pilot's ability to fly with instruments.

The unplanned loss of all visual references is a critical situation for a pilot who is relying solely on visual references to the ground, whether during the day or at night. There is a known risk of rapid loss of helicopter control if visual references are lost.

Once a pilot in this situation becomes aware of what is happening, his or her stress level tends to rise rapidly. Maintaining control of the aircraft therefore requires fast reaction times. A pilot without recent knowledge of and practice with instrument flight rules runs the risk of making inappropriate manoeuvres.

Given the established correlation between an abnormal flight attitude and a loss of flight control, it is highly likely that, in this occurrence, the pilot lost control of the helicopter as a result of spatial disorientation.

2.3 Limited experience with night visual flight rules flight

Night flight requires pilots to develop additional skills so they can operate in an environment that is different from that of daytime flight. To compensate for the reduced visual acuity, which is the main source of information to maintain spatial orientation, pilots must refer more frequently to their flight instruments on night flights. This skill is initially acquired through adequate training. Although the regulations require pilots to complete a minimum number of hours of night flight and instrument flight before applying to add a night rating to their pilot licence, they are not required to take theoretical ground training on the specifics of night flight, such as spatial disorientation, optical and sensory illusions, night vision, regulations, decision making, or fatigue. The pilot's exposure to these topics is left to the discretion of the instructor delivering the training.

In this occurrence, the pilot had only 56.2 hours of night flight experience, including 46.1 hours as pilot-in-command, over a 12-year period (October 2006 to 01 February 2018). None of the information collected made it possible for the TSB to determine whether the pilot had acquired theoretical knowledge on spatial disorientation during his night flight training. Before the accident, the last night flight recorded in the pilot's personal flight log took place on 09 September 2017—almost 5 months before the occurrence. Given the pilot's total number of flying hours, his training, and his limited night flight experience, it is likely that the pilot did not have the skills needed to handle a significant reduction in visual references to the ground.

2.4 Recency of knowledge

Pilots use their experience and knowledge to manage flight-related risks. However, statistical data collected by the TSB show that pilots' total flight experience is not a factor that protects them from accidents when they are flying under VFR and lose visual references after entering instrument meteorological conditions (IMC).

During a night flight, given the darkness, it is difficult or even impossible to perceive a deterioration of meteorological conditions. Pilots flying at night need to be aware of this so that they are better able to manage the risk of involuntarily entering IMC. Additional skills and knowledge must be acquired and periodically evaluated so that pilots maintain an adequate level of knowledge.

The requirements to obtain a night rating do not take into account the pilot's level of general night-flight knowledge (e.g. optical illusions, spatial disorientation, flight planning, regulations, and decision making). Moreover, the recency requirement in the regulations does not require pilots who have a night rating to maintain their skills in conducting basic manoeuvres using instruments to maintain control of the aircraft without visual references. For example, a pilot may have a night rating, fly only during the day for several years, then conduct a night flight with no regulatory requirement other than 5 night landings and 5 night takeoffs if he or she wishes to carry passengers on board. Outdated knowledge and limited experience in instrument flight do not help pilots deal with critical situations such as a significant reduction in visibility during a night flight.

Instrument flight skills, as well as skills relating to emergency measures, are essential for the safety of night flight. However, there is a difference between being qualified and being competent. Instrument flight is a complex skill; pilots must practise the exercises frequently so that they can maintain their skills at an acceptable level. Reviewing theoretical knowledge of considerations specific to night flight can make pilots more aware of their situation and help them make the right decisions. Good flight planning also helps pilots reduce their risk of losing visual references during flight. However, unexpected situations can occur, and pilots may have to rely on their instrument flight skills to maintain control of the aircraft and locate their visual references.

There is no indication in the pilot's personal flight logbook that he had practised dual-instrument flight with a qualified instructor after obtaining his night rating in 2007, and there are no entries concerning any updates to theoretical knowledge.

If the *Canadian Aviation Regulations* (CARs) do not require pilots to maintain their night-flying skills in order to use the privileges of a night rating, there is a risk that they will be unable to recognize spatial disorientation and react appropriately, increasing the risk of an accident resulting from a loss of control.

If the CARs do not require pilots who conduct night VFR flights to undergo recurrent assessments in the form of dual-instrument flights with a qualified instructor, there is an increased risk that, in the event of a loss of visual references, pilots will not be able to maintain control of the aircraft or regain control in time to avoid an accident.

2.5 Decision making

The investigation was unable to determine whether the pilot was aware of the weather conditions along the flight path. The fact that the flight was made despite the unfavourable weather forecast indicates limited awareness of the weather situation, which led to the decision to proceed with the initial flight plan. Several factors may explain the pilot's decision to take off despite the weather forecast issued for the flight path:

- The return flight was planned for that same evening.
- The weather conditions at the point of departure were favourable for VFR flight.
- The route was familiar.

The flight itinerary that the pilot filed with the responsible person included a planned return that same evening. The tendency to stick to the initial plan is an unconscious cognitive bias that involves continuing with an initial plan of action despite changing conditions. And, if the passengers on board expected to return that same evening, they may have exerted real or perceived pressure on the pilot. The fact that the weather conditions before takeoff from Saint-Georges de Beauce were favourable for VFR flight may also have supported the pilot's decision to take off.

The pilot was familiar with the route, having already made the same flight twice during the day, about 8 months before the accident. The pilot therefore had experience flying over the same area at least twice. These 2 positive experiences (in which the results matched the expectations) may have influenced the pilot's perception of the situation. However, a route flown during the day does not have the same characteristics as when it is flown at night. During a daytime flight above a region that is considered to be populated, such as Centre-du-Québec, it can be difficult to imagine that some areas do not have adequate ground lighting when night falls. If visibility is good, well-lit areas may compensate for areas with less lighting. However, if visibility deteriorates during flight to the point where the pilot is unable to see beyond a zone with little ground lighting, the risk of losing visual references to the surface increases, even in an area that is considered populated. Consequently, the choice of flight route between 2 points may differ depending on whether the flight is made during the day or at night.

During a night flight, given the darkness, it is difficult or even impossible to perceive deteriorating weather conditions. Therefore, a night VFR flight path should be determined in consideration of only those areas that provide the most ground lighting possible, and not necessarily follow a straight line. In straight flight, the risk of losing sight of the visual references required to maintain control of an aircraft is increased.

In 2016, the TSB issued Recommendation A16-08 concerning the lack of clarity in the practical meaning of the definition of a "flight with visual reference to the surface." The Board is pleased that TC is taking measures to address this safety deficiency by conducting awareness and education activities, to be followed by proposed regulatory amendments. However, the fact remains that until the details of the proposed regulatory amendments are fully known, the TSB cannot evaluate whether these measures will fully address the safety deficiency associated with night VFR flights. If the CARs do not clearly define visual references to the surface, night flights may be conducted with inappropriate visual references, increasing the risk of accidents involving a loss of control or controlled flight into terrain.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

1. It is highly likely that the pilot encountered unfavourable weather conditions that resulted in a loss of visual references to the ground.

2. It is highly likely that the pilot lost control of the helicopter as a result of spatial disorientation.

3. Given the pilot's total number of flying hours, his training, and his limited night flight experience, it is likely that the pilot did not have the skills needed to handle a significant reduction in visual references to the ground.

3.2 Findings as to risk

1. If the *Canadian Aviation Regulations* (CARs) do not require pilots to maintain their night-flying skills in order to use the privileges of a night rating, there is a risk that they will be unable to recognize spatial disorientation and react appropriately, increasing the risk of an accident resulting from a loss of control.

2. If the CARs do not require pilots who conduct night visual flight rules flights to undergo recurrent assessments in the form of dual-instrument flights with a qualified instructor, there is an increased risk that, in the event of a loss of visual references, pilots will not be able to maintain control of the aircraft or regain control in time to avoid an accident.

3. If the CARs do not clearly define visual references to the surface, night flights may be conducted with inappropriate visual references, increasing the risk of accidents involving a loss of control or controlled flight into terrain.

3.3 Other findings

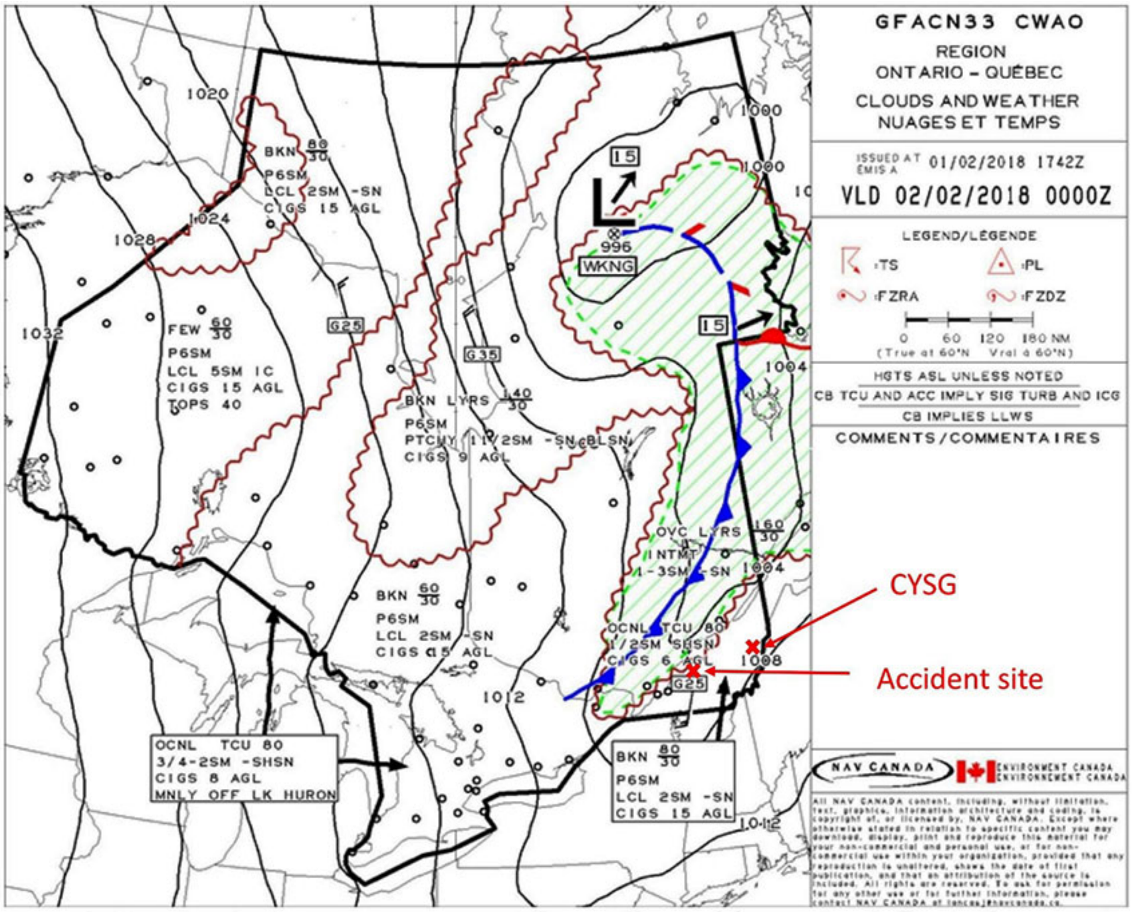
1. The regulations in effect at the time of the accident did not require theoretical ground training on considerations specific to night flight (such as spatial disorientation, optical and sensory illusions, night vision, human factors, pilot decision making, fatigue) to obtain a night rating.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 30 January 2019. It was officially released on 18 February 2019.

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.

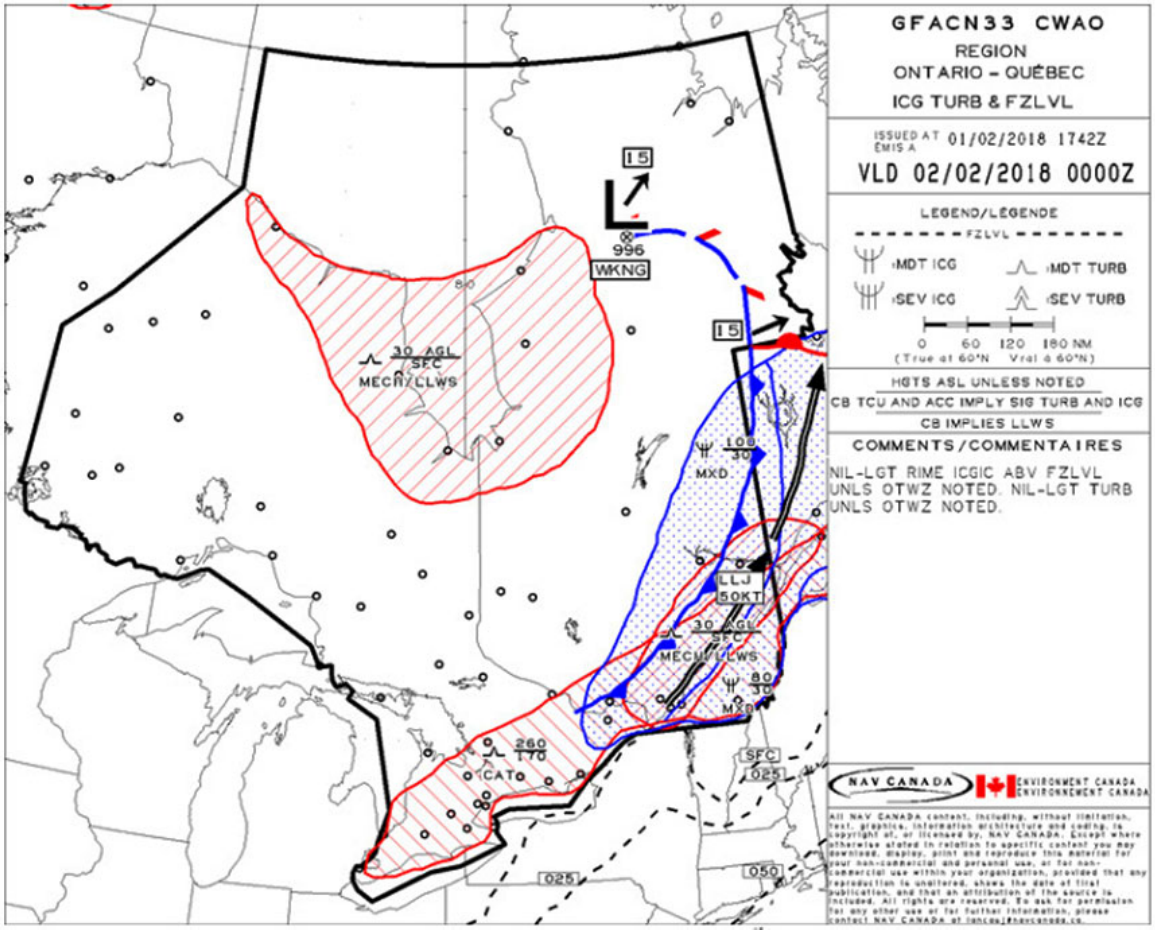
APPENDICES

Appendix A – Clouds and weather graphical area forecast chart issued at 1242 on 01 February 2018 and valid at 1900



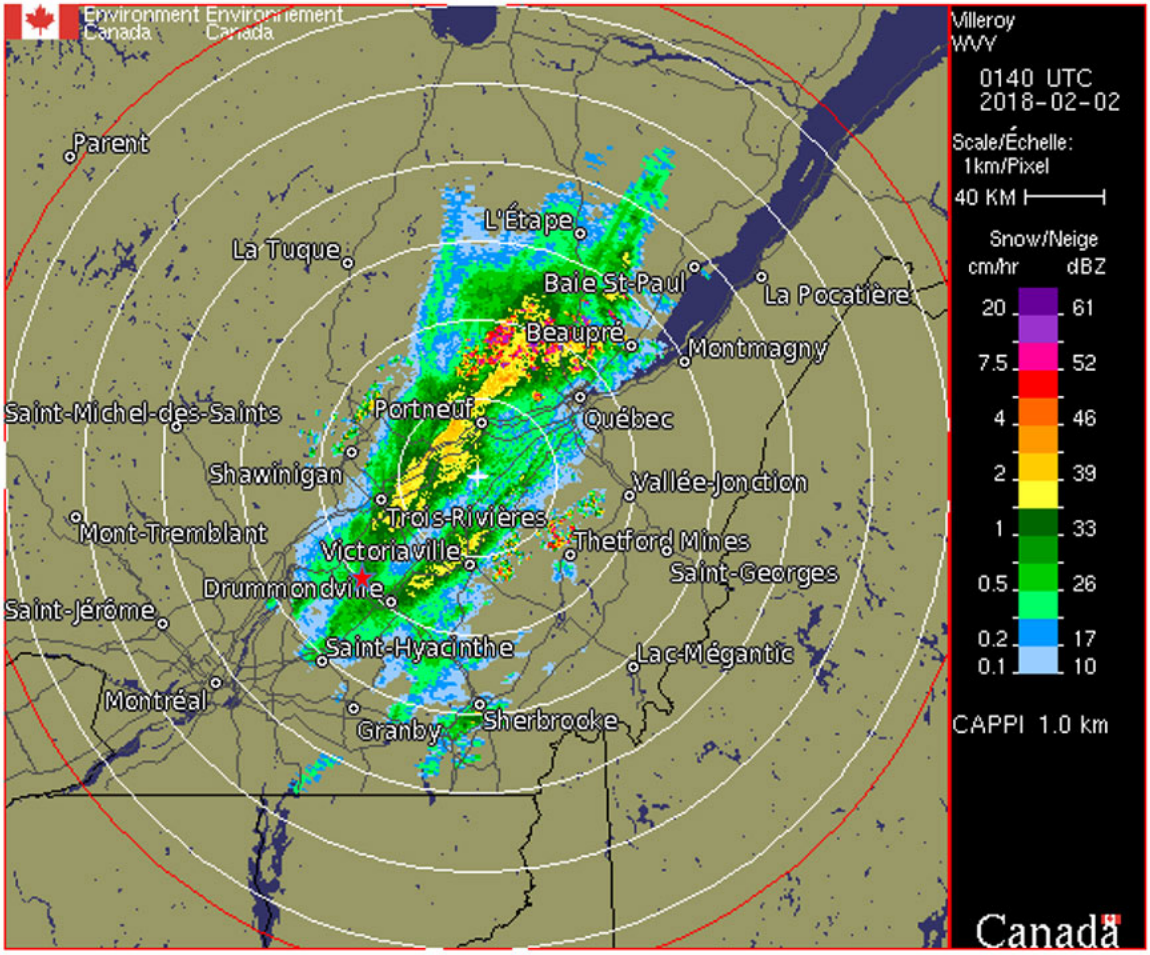
Source: NAV CANADA, with TSB annotations

Appendix B – Icing, turbulence, and freezing levels graphical area forecast chart issued at 1242 on 01 February 2018 and valid at 1900



Source: NAV CANADA

Appendix C – Screen capture of Villeroy weather radar at 2040 on 01 February 2018



Note: The red star indicates the accident site.
Source: Environment and Climate Change Canada, with TSB annotations

Appendix D – Results of examination of flight instruments recovered from the wreckage

Instruments examined	Witness marks at impact
Altimeter	No witness marks
Attitude indicator	81° rightward roll / 25° forward tilt
Speed indicator	80 knots
Vertical speed indicator	1750 fpm
Compass	No witness marks
Manifold pressure indicator	23 inHg*
Engine rpm	Approximately 113%**
Main rotor rpm	Approximately 107%***
Oil pressure indicator	85 psi

* According to the *R44 Pilot's Operating Handbook and FAA Approved Rotorcraft Flight Manual*, the permitted maximum continuous power for take-off at the existing outside temperature and pressure altitude was around 22.5 inches of mercury (inHg). (Source: Robinson Helicopter Company, *R44 Pilot's Operating Handbook and FAA Approved Rotorcraft Flight Manual*, RTR 461 [October 21, 2016], Section 2: Limitations, p. 2-9.)

** The normal operating range is 101% to 102%, but the reading of 113% may have been influenced by the impact forces.

*** The normal operating range is 101% to 102%, but the reading of 107% may have been influenced by the impact forces.

Appendix E – Results of examination of warning lights

Warning light	Observation of filament	Status of light at time of impact
MR TEMP	Filament intact	Light off
ROTOR BRAKE	Filament intact	Light off
CARBON MONOXIDE	Filament intact	Light off
MR CHIP	Filament broken	Uncertain
STARTER ON	Filament broken	Uncertain
ALTERNATOR	Filament broken	Uncertain
TR CHIP	Filament broken	Uncertain
CLUTCH	Filament broken	Uncertain
LOW RPM	Filament broken	Uncertain
LOW FUEL	Filament broken	Uncertain
OIL	Filament broken	Uncertain
ENGINE FIRE	Filament broken	Uncertain
GOVERNOR OFF	Filament broken	Uncertain

Appendix F – Acceptable recurrent training program measures according to Standard 421.05(2) of the *Canadian Aviation Regulations*: Recency requirements

Acceptable measures recognized by Transport Canada	TSB analysis
(a) completion of a flight review conducted by the holder of a flight instructor rating in the same category, shall include all items normally covered during the flight test for the issue of that permit or licence	An in-flight review generally requires • access to a qualified flight instructor who is usually affiliated with a flight school; • access to an aircraft; and • a financial outlay. This avenue is not likely to be used by pilots who have a private licence.
(b) attendance at a safety seminar conducted by Transport Canada Aviation	Safety seminars tend to be given sporadically across Canada and are mainly offered in larger centres. They do not necessarily address the specific needs of each pilot.
(c) successful completion of a recurrent training program designed to update pilot knowledge, which could include subject areas such as human factors, meteorology, flight planning and navigation, and aviation regulations, rules and procedures that has been approved by the Minister as being satisfactory for those purposes	Recurrent training programs are mandatory and offered only to pilots employed by airlines. These programs relate to the airlines' specific operations and are not available to private pilots.
(d) completion of the self-paced study program produced annually in the *Transport Canada Aviation Safety Newsletter*, which is designed to update pilot knowledge in the subjects specified in (c) above. The completed copy shall be the most current published by date and shall be retained by the licence holder	*The Aviation Safety Letter (ASL)* is published quarterly and is only available online. This self-study program consists of questions to be answered (the answers and references are provided in the publication). The topics covered do not necessarily address the specific needs of each pilot.
(e) completion of a training program or Pilot Proficiency Check as required by Parts IV, VI or VII of the *Canadian Aviation Regulations*	The pilot proficiency check (PPC) is an in-flight examination conducted under the supervision of a pilot certified by the Minister of Transport and is aimed at professional pilots employed by airlines. It does not apply to private pilots.
(f) completion of the skill requirements for issue or renewal of a pilot permit, licence or rating, including night rating, VFR over-the-top rating, instrument rating, multi-engine class rating, flight instructor rating, landplane or seaplane rating	The addition of a new qualification or licence is not the most desirable approach for satisfying skills recency requirements.
(g) completion of the written examination(s) for a permit, licence or rating	These written examinations are administered by Transport Canada and are not designed for pilots who merely wish to keep their skills up to date without obtaining another permit, licence, or rating.