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

AVIATION INVESTIGATION REPORT A15C0163

Icing encounter, loss of control, and collision with terrain

Wasaya Airways Limited Partnership
Cessna 208B, C-FKDL
Pickle Lake, Ontario, 10 nm N
11 December 2015

Canada

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Summary

The Wasaya Airways Limited Partnership Cessna 208B Caravan (registration C-FKDL, serial number 208B0240) departed Pickle Lake Airport, Ontario, on 11 December 2015 at 0900 Eastern Standard Time under visual flight rules as flight WSG127 to Angling Lake / Wapekeka Airport, Ontario, with the pilot and a load of cargo on board. At 0908, the flight levelled off at about 4600 feet above sea level. At 0909, WSG127 descended and turned about 120° to the right, then collided with the southeast side of Tarp Hill at an elevation of 1460 feet above sea level. The pilot was fatally injured, and the aircraft was destroyed. There was no post-impact fire. The 406-megahertz emergency locator transmitter activated on impact, but no signal was emitted.

Le présent rapport est également disponible en français.

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1.0 Factual information

1.1 History of the flight

On 11 December 2015, the pilot of Wasaya Airways Limited Partnership (Wasaya) flight 127 (WSG127) reported for duty at the Wasaya hangar at Pickle Lake Airport (CYPL), Ontario, at about 0815.[1] The air taxi flight was to be the first of 3 cargo trips in the Cessna 208B Caravan (registration C-FKDL, serial number 208B0240) planned from CYPL to Angling Lake / Wapekeka Airport (CKB6), Ontario. The first flight was planned to depart at 0900.

The pilot went to the Wasaya apron and conducted a pre-flight inspection of C-FKDL while a ground crew was loading cargo. A Wasaya aircraft fuel-handling technician confirmed with the pilot that the planned fuel load was 600 pounds[2] per wing of Jet A fuel. After completing the fueling, the technician used the cockpit fuel-quantity indicators to verify that the distribution was 600 pounds per wing.

The pilot returned to the hangar and received a briefing from the station manager regarding the planned flights. The pilot was advised that the first officer assigned to the flight had been reassigned to other duties in order to increase the aircraft's available payload and load a snowmobile on board.

The pilot completed and signed a Wasaya flight dispatch clearance (FDC) form for WSG127, and filed a copy of it, along with the flight cargo manifests, in the designated location in the company operations room. The FDC for WSG127 showed that the flight was planned to be conducted under visual flight rules (VFR), under company flight-following, at an altitude of 5500 feet above sea level (ASL). Time en route was calculated to be 66 minutes, with fuel consumption of 413 pounds.

The pilot returned to the aircraft on the apron. Loading and fueling were complete, and the pilot conducted a final walk-around inspection of C-FKDL. Before entering the cockpit, the pilot conducted an inspection of the upper wing surface.

At 0854, the pilot started the engine of C-FKDL and conducted ground checks for several minutes. At 0858, the pilot advised on the mandatory frequency (MF), 122.2 megahertz (MHz), that WSG127 was taxiing for departure from Runway 09 at CYPL.

WSG127 departed from Runway 09 at 0900, and, at 0901, the pilot reported on the MF that the flight was airborne. The flight climbed eastward for several miles and then turned left toward the track to CKB6. At about 3000 feet ASL, WSG127 briefly descended about 100 feet over 10 seconds, and then resumed climbing. At 0905, the pilot reported on the MF that WSG127 was clear of the MF zone.

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

2 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

WSG127 intercepted the track to CKB6 and climbed northward until the flight reached a peak altitude of about 4600 feet ASL at 0908:41, and then began descending at 0908:46. At 0909:16, the flight made a sharp right turn of about 120° as it descended through about 4000 feet ASL. At 0909:39, the descent ended at about 2800 feet and the aircraft climbed to about 3000 feet ASL before again beginning to descend. At approximately 0910, WSG127 collided with trees and terrain at an elevation of 1460 feet ASL during daylight hours.

1.2 *Injuries to persons*

Table 1. Injuries to persons

	Crew	Passengers	Others	Total
Fatal	1	–	–	1
Serious	–	–	–	–
Minor/none	–	–	–	–
Total	1	–	–	1

1.3 *Damage to aircraft*

The aircraft was destroyed by impact forces.

1.4 *Other damage*

The cargo was destroyed by impact forces. Minor environmental damage resulted from tree strikes and fuel spillage.

1.5 *Personnel information*

Table 2. Personnel information

	Pilot
Pilot licence	Commercial pilot licence
Medical expiry date	01 June 2016
Total flying hours	2990
Flight hours on type	245
Flight hours in the last 7 days	22.1
Flight hours in the last 30 days	43
Flight hours in the last 90 days	124
Flight hours on type in the last 90 days	124
Hours on duty before occurrence	1
Hours off duty before work period	13

Other than a deficiency in initial training time (described in Section 1.17.1.5), training records showed that the pilot's qualifications, certification, and recency met the requirements of Wasaya's *Company Operations Manual* (COM) and *Canadian Aviation Regulations* (CARs) section 703.88. The pilot was certified and qualified for the flight in accordance with existing regulations.

At the time of the accident, the pilot held a commercial pilot licence valid for single- and multi-engine landplanes, with a Group 1 instrument rating valid until 01 June 2016. The pilot's most recent medical examination had been on 28 May 2015. The pilot held a Category 1 medical certificate that was valid until 01 June 2016 and had a limitation requiring glasses or contact lenses to be worn. The pilot was wearing contact lenses at the time of the accident.

The pilot had been employed by Wasaya since 2013 on other aircraft types. The company had provided initial and annual recurrent training in crew resource management and pilot decision making.

In July 2015, the pilot received initial Cessna 208B training and achieved pilot competency certification as a captain on the Cessna 208B on 28 July 2015, which was followed by 10 days of line indoctrination before release to line service. Subsequently, the pilot received 8 hours of Cessna 208 simulator training and successfully completed the online Caravan-specific Cold Weather Operations Course[3] provided by Cessna. The pilot passed a Cessna 208B pilot proficiency check on 13 October 2015; the check was valid until 01 November 2016 and certified the pilot for both single-pilot and multi-crew operations as captain.

The pilot's work schedule provided sufficient time free from duty to allow for adequate rest. No information was available regarding the pilot's sleep history.

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3 The Cessna Cold Weather Operations Course provides a detailed review of cold weather meteorology, including icing; a comprehensive description of the Cessna 208B ice-protection systems and their operating procedures and limitations; and strategies for how best to avoid or exit icing conditions.

1.6 Aircraft information

Table 3. Aircraft information

Manufacturer	Cessna
Type, model, and registration	208B, Caravan, C-FKDL
Year of manufacture	1990
Serial number	208B0240
Certificate of airworthiness issue date	19 June 2013
Total airframe time	36 073.8 hours / 58 324 cycles
Engine type (number of engines)	Pratt & Whitney Canada PT6A-114A (1)
Propeller/rotor type (number of propellers)	McCauley 3GFR34C703-B (1)
Maximum allowable take-off weight	9062 pounds*
Recommended fuel type(s)	Jet A, Jet A-1, Jet B
Fuel type used	Jet A

* AeroAcoustics Aircraft Systems, Inc., *Installation Manual for AeroAcoustics Aircraft Systems, Inc. Aircraft Payload Extender Modification for the Cessna Caravan*, Supplemental Type Certificate SA01213SE, Pilot's Operating Handbook Supplement, p. 2.

1.6.1 General

The Cessna Caravan 208B aircraft is a tricycle fixed-gear, high-wing aircraft equipped with a single PT6A-114A (675) horsepower turboprop engine and, as manufactured, has a maximum take-off weight of 8750 pounds. It is certified for operation by a single pilot, but has seating, controls, and instruments for a second pilot.

C-FKDL was fitted with a McCauley aluminum 3-bladed, constant-speed, full-feathering, and reversible propeller. The aircraft was certified for day and night VFR as well as instrument flight rules (IFR) flight, and it was prohibited from flight in known or forecast icing conditions. The prohibition was prominently placarded in the cockpit in view of the pilot (Figure 1).

The C208B can be fitted to carry a crew of 2 and up to 9 passengers, or a combination of freight and passengers, and may be equipped with a cargo pod. C-FKDL was configured for cargo and was equipped with a cargo pod on the underside of the fuselage.

Figure 1. C-FKDL cockpit placard

On 07 December 2015, engine and airframe inspections of C-FKDL had been completed (at 36 063.0 airframe hours). After these inspections, the aircraft had subsequently flown 10.8 hours before the accident. A review of the technical documents indicates that C-FKDL had no

known defects or deferrals. The aircraft had a valid certificate of airworthiness and was maintained in compliance with the current approved Wasaya maintenance schedule.

The company's *Maintenance Control Manual* specified that "Elementary Work or Servicing shall be performed in accordance with the methods, practices, and procedures recommended by the manufacturer."[4]

1.6.2 Automatic flight control system

C-FKDL was equipped with a King KFC-150 flight control system that included an autopilot and flight director. In the Environment Conditions section of the Cessna Supplement S1 to the pilot's operating handbook (POH) for the Cessna 208B,[5] autopilot operation is prohibited when operating in icing conditions that are outside the conditions defined by Title 14 of the U.S. *Code of Federal Regulations* (14 CFR) Part 25, Appendix C.

1.6.3 Aircraft payload extender modification

C-FKDL was fitted with AeroAcoustics Aircraft Systems, Inc. Supplemental Type Certificate (STC) aircraft payload extender (APE) II STC SA00392SE (Stall Fence) and APE III STC SA01213SE (Axle), which increased the maximum take-off weight to 9062 pounds. The STC specified that the maximum weight for flight in known icing conditions with a cargo pod installed was 8550 pounds.

1.6.4 Icing certification

Icing conditions used for aircraft certification are

> defined by the variables of the cloud liquid water content, the mean effective diameter of the cloud droplets, the ambient air temperature, and the interrelationship of these three variables.[6]

The maximum mean effective diameter of water droplets used for certification is 40 micrometres (µm) for intermittent conditions and 50 µm for continuous conditions.

Freezing drizzle consists of supercooled liquid water drops with diameters of between 50 and 500 µm.[7] Because of the large size and mass of the drops, freezing drizzle is outside the conditions in which the aircraft is certified to operate.

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4 Wasaya Airways Limited Partnership, *Maintenance Control Manual*, Revision 10 (24 December 2014), section 2.3, p. 12.

5 *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual Supplement S1: Known Icing Equipment*, Revision 5 (10 February 2009), p. S1-17.

6 Federal Aviation Administration (FAA), *Code of Federal Regulations*, Title 14, Part 25, Appendix C.

7 Federal Aviation Administration (FAA), Advisory Circular (AC) 91-74B: Pilot Guide: Flight In Icing Conditions (08 October 2015), p. 2.

Many Cessna 208B aircraft are equipped with ice-protection systems, as defined by the U.S. *Federal Aviation Regulations* (FARs) Part 23.1419, that permit certification of the aircraft for flight in icing conditions. The certification requires compliance with the *Cessna Model 208B (675 SHP) Pilot's Operating Handbook and FAA Approved Airplane Flight Manual* (AFM) Supplement S1 and various airworthiness directives.[8] The following optional equipment, approved by Cessna and the Federal Aviation Administration (FAA), must be installed and fully operational:

- wing and wing strut leading-edge de-icing boots
- horizontal stabilizer leading-edge de-icing boots
- vertical stabilizer leading-edge de-icing boot
- propeller anti-icing boots
- windshield anti-icing panel
- pitot–static tube heating system
- standby electrical system
- ice detector light
- engine inertial separator (required equipment on standard airplanes)
- heated stall-warning system (included equipment on standard airplanes)
- functional low-airspeed awareness system
- additional equipment specified by optional Accessory Kit AK208-6 (lower main landing-gear leg leading-edge de-icing boots, Cargo pod nose-cap de-icing boot)

For Cessna 208B aircraft that are certified for flight in known icing conditions, the Cessna POH icing supplement advises that the aircraft is certified to operate under conditions specified in 14 CFR Part 25, Appendix C, and includes a warning that flight is prohibited outside of those conditions, including in freezing drizzle.[9]

In May 2007, Wasaya determined that AD2007-10-15[10] was not applicable to C-FKDL because the aircraft was prohibited from flight in known or forecast icing conditions. C-FKDL was equipped with pneumatic de-icing boots on the leading edges of the wing, the wing strut, and the horizontal and vertical stabilizers, and with electrically heated propeller anti-icing boots, a windshield anti-icing system, a heated stall-warning system, and pitot–static system heat. The aircraft was not equipped with cargo pod nose-cap or main landing-gear leg de-icing boots or with a low-airspeed awareness system.

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8 Federal Aviation Administration (FAA), Airworthiness Directives (ADs) 96-09-15, 2006-01-11R1, and 2007-10-15.

9 *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual Supplement S1: Known Icing Equipment*, Revision 5 (10 February 2009), p. S1-16.

10 FAA Airworthiness Directive 2007-10-15 supersedes a previous AD and requires the installation of a functional low-speed awareness system on aircraft that are not currently prohibited from flight in known or forecast icing.

1.6.5 *ICEX II*

ICEX II is a silicone-based liquid compound used to reduce adhesion of ice to treated surfaces and to increase ice shedding.[11] ICEX II is used on a wide variety of aircraft with boots, including the Cessna 208B. Cessna recommends applying ICEX II as an aircraft servicing task "every 50 flight hours to airframe de-icing boots and every 15 flight hours to propeller de-icing boots."[12]

In Canada, commercially operated aircraft must be maintained in accordance with a maintenance schedule approved by Transport Canada (TC).[13] Before May 2006, Wasaya applied ICEX II only to airframe de-icing boots on its Caravan fleet on a schedule of a maximum interval of 50 hours between applications. In May 2006, Wasaya revised its approved maintenance schedule addendum to specify a maximum application interval of 100 hours. No records were found at Wasaya or TC regarding justification for the interval increase, although the maintenance schedule amendment was approved by TC.

At the time of this accident, Wasaya's approved Cessna 208B maintenance schedule specified that ICEX II was to be applied to the airframe de-icing boots at a maximum interval of 100 hours during the icing season.[14] The company defined the icing season as 15 September to 15 May. This task was being performed by Wasaya aircraft maintenance engineers.

ICEX II had been applied to the leading-edge de-icing boots of C-FKDL 10.6 flight hours before the accident.

The Wasaya maintenance schedule addendum did not include the Cessna recommendation to apply ICEX II to the propeller anti-icing boots at maximum intervals of 15 hours. A review of Wasaya Caravan maintenance records showed that there was no record of ICEX II having been applied to the Caravan propeller anti-icing boots.

1.6.6 *Aircraft performance*

1.6.6.1 *Weight and balance*

The aircraft was loaded with a snowmobile, 2 laundry washing machines, and groceries; the total load weight was 2646 pounds. The snowmobile spanned cabin cargo zones 1, 2, and 3. One washing machine was loaded in zone 3, and the second spanned zones 4 and 5 behind the snowmobile. The load was distributed within the specified weight limits for each cargo zone.

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11 Cessna Aircraft Company, *Model 208/208B Maintenance Manual* (01 September 2014), section 12-31-00-3 (Revision 28).

12 Ibid.

13 *Canadian Aviation Regulations* (CARs), section 605.86.

14 Wasaya Airways Limited Partnership, Cessna 208B/208 Approved Aircraft Maintenance Schedule No. P1464THU (Revision 11) (29 October 2014).

Investigators calculated the take-off weight for WSG127 at 9009 pounds, with a centre of gravity 202.75 inches aft of datum (Appendix A). The weight and centre of gravity were within the prescribed limits for an aircraft prohibited from operating in icing conditions.

1.6.6.2 *Climb performance*

The APE III System STC installed on C-FKDL included climb performance data for the modified C208B aircraft.[15] The cruise climb chart showed that the aircraft was capable of climbing at about 800 feet per minute (fpm) between 3000 and 4600 feet ASL at 105 knots indicated airspeed (KIAS).[16]

For its Cessna 208B fleet, Wasaya specified the recommended climb speed as 120 KIAS with power set at 1650 foot-pounds torque and propeller revolutions per minute set at 1750.[17]

1.6.6.3 *Stall speed*

The APE III POH Supplement provided stall speeds for the maximum take-off weight of 9062 pounds (Figure 2).

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15 AeroAcoustics Aircraft Systems Inc., Supplemental Type Certificate SA01213SE *Pilot's Operating Handbook*, Supplement, p. 12.

16 Cessna provides airspeed calibration charts for the Cessna 208B at a weight of 8750 pounds and with the power set for level flight. The chart shows that, under these conditions, indicated and calibrated airspeed are equal through the range of 100 to 175 knots. (Source: *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual,* Revision 23 (04 May 2007), p. 5-12.)

17 Wasaya Airways Limited Partnership, *Caravan C208 Standard Operating Procedures*, Original Issue (February 2008), p. 2-6.

Figure 2. APE III stall speeds (Source: AeroAcoustics Aircraft Systems Inc., Supplemental Type Certificate SA01213SE Pilot's Operating Handbook, Supplement, p. 5)

CONDITIONS:
Power Lever - Idle.
Fuel Condition Lever - High Idle

NOTES:
1. Altitude loss during a stall recovery may be as much as 300 feet from a wings-level stall and even greater from a turning stall.
2. KIAS values are approximate.

WEIGHT LB	FLAP DEFLECTION	ANGLE OF BANK							
		0°		30°		45°		60°	
		KIAS	KCAS	KIAS	KCAS	KIAS	KCAS	KIAS	KCAS
9062	UP	63	78	68	84	75	93	90	111
	10°	61	71	65	76	73	85	87	101
	20°	55	65	59	70	65	77	78	92
	30°	50	61	53	65	58	72	71	86

No information was available regarding the stall speed at other weights or with power above idle.

1.6.6.4 Cessna 208B performance in icing conditions

Ice accretion on an airframe increases aircraft weight and drag and decreases lift. Ice accretion on a propeller reduces the thrust produced by the propeller. These changes result in degradation of aircraft performance, including increased stall speed and reduced rate of climb. Operation of the de-icing boots does not remove all ice on the boots, and residual ice remaining after boot operation results in degraded aircraft performance. Additionally, asymmetrical ice accumulation or shedding on aircraft surfaces can result in unpredictable aerodynamic effects.

The risk posed by in-flight icing was identified in manuals relevant to the operation of WSG127.

The POH for the Cessna 208B contains the following warning in bold type:

> Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice build-up on protected surfaces exceeding the capability of the ice protection system, or may result in ice forming aft of the protected surfaces. This ice may not be shed using the ice protection systems, and may seriously degrade the performance and controllability of the airplane.[18]

[18] *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual*, Revision 23 (04 May 2007), p. 2-21.

According to the Cessna supplement S1 to the C208B POH,

> [w]henever icing conditions are encountered, immediate action should be taken to exit these conditions before airplane performance is degraded to a point where a climb, which is normally the best action to take, may not be achievable due to the residual ice build up.[19]

Wasaya's standard operating procedures (SOPs) specify that

> [i]f icing conditions are inadvertently entered, the autopilot should immediately be disengaged and the aircraft should be hand-flown until clear of the icing conditions. Any icing conditions should be vacated immediately and the emergency section of the SOP should be referred to.[20]

For Cessna 208B aircraft that are certified for flight in icing conditions, the POH Supplement provides a warning that "flight in conditions outside of 14 CFR Part 25 Appendix C is prohibited,"[21] and specifies a minimum airspeed limitation in icing conditions of 120 KIAS with flaps up, or 110 KIAS with flaps up when climbing to escape icing conditions.[22] If these airspeeds cannot be maintained, or if there is a 10-knot decrease in airspeed that cannot be prevented by an increase to maximum continuous power, then continued flight in icing conditions is prohibited.[23]

The POH supplement states that ice accumulation on the Cessna 208B "may result in a 20 KIAS increase in stall speed" and that "the aural stall warning system does not function properly in all icing conditions and should not be relied upon to provide adequate stall warning in icing conditions."[24]

1.6.7 Emergency locator transmitter

C-FKDL was equipped with a Kannad 406-MHz automatic fixed compact emergency locator transmitter (ELT) in the tail section of the aircraft. If the ELT is activated on impact or manually by the crew, it transmits signals on both 406 MHz and 121.5 MHz. The 406-MHz frequency is detected by the Cospas-Sarsat search-and-rescue (SAR) satellite system,[25] which can transmit the downed aircraft's position and identification to the Canadian Mission Control Centre. The Canadian Mission Control Centre then passes this information along to

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19 *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual Supplement S1: Known Icing Equipment*, Revision 5 (10 February 2009), p. S1-3.

20 Wasaya Airways Limited Partnership, *Caravan C208 Standard Operating Procedures*, Original Issue (February 2008), p. 2-12.

21 *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual Supplement S1: Known Icing Equipment*, Revision 5 (10 February 2009), p. S1-16.

22 Ibid., p. S1-18.

23 Ibid., p. S1-17.

24 Ibid., p. S1-49.

25 Cospas is an acronym for a Russian phrase that translates to Space System for Search of Vessels in Distress. Cospas-Sarsat is the International Satellite System for Search and Rescue.

one of 3 Joint Rescue Coordination Centres in Canada, depending on the location of the signal.[26]

1.6.8 Satellite tracking system

C-FKDL was equipped with an ISAT-100 satellite flight tracking system (serial number 1856), manufactured by SKYTRAC Systems.

1.7 Meteorological information

1.7.1 General

The pilot used a computer available in the pilot room at Wasaya's base at CYPL to prepare the FDC form. The computer had Internet access for obtaining weather information. No record indicating which weather information the pilot reviewed during pre-flight preparations was available.

1.7.2 Pre-flight weather

1.7.2.1 General

This section contains weather information that was readily available from the NAV CANADA Aviation Weather Web Site during the pre-flight preparations for WSG127.

1.7.2.2 Departure

An aerodrome forecast (TAF) was issued for CYPL at 0738. For the period from 0800 to 1300, the following conditions were forecast: wind 020° true (T) at 8 knots, visibility greater than 6 statute miles (sm), light snow, overcast clouds based at 1500 feet above ground level (AGL), with transitory conditions from 1100 to 1300 of visibility greater than 6 sm and overcast clouds based at 1500 feet AGL.

The 0800 aerodrome routine meteorological report (METAR) for CYPL was as follows: wind 040°T at 13 knots, visibility 10 sm with light snow, overcast stratocumulus clouds based at 1000 feet AGL, temperature −5 °C, dew point −7 °C, altimeter setting 29.72 inches of mercury (in. Hg).

1.7.2.3 Destination

CKB6 does not have an aviation weather observation program, and no METARs or TAFs are issued for it. The closest airport to CKB6 with METARs and TAFs is Big Trout Lake Airport (CYTL), Ontario, 11 nautical miles (nm) west of CKB6.

An amended TAF was issued for CYTL at 0648 (Table 4).

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[26] Joint Rescue Coordination Centres are located in Halifax, Nova Scotia; in Trenton, Ontario; and in Victoria, British Columbia.

Table 4. CYTL amended TAF issued at 0648

Period	Forecast
0600 to 0900	Wind 360°T at 7 knots, visibility 2 sm with light snow and mist, overcast clouds based at 300 feet AGL
	Transitory conditions from 0600 to 0900 of visibility greater than 6 sm with no significant weather, and overcast clouds based at 900 feet AGL
0900 to 1500	Wind 360°T at 7 knots, visibility 2 sm with light snow, overcast clouds based at 400 feet AGL
	Transitory conditions from 0900 to 1500 of visibility greater than 6 sm with no significant weather, and overcast clouds based at 1000 feet AGL
	30% probability between 0900 to 1300 of overcast clouds based at 300 feet AGL

The 0800 automated METAR for CYTL was as follows: wind 350°T at 6 knots, wind direction variable from 310°T to 040°T, visibility 3 sm with mist, overcast clouds based at 300 feet AGL, temperature −6 °C, dew point −7 °C, altimeter setting 29.81 in. Hg.

1.7.2.4 Graphical area forecast

Graphical area forecasts (GFAs) describe

> the most probable meteorological conditions expected to occur between the surface and 24,000 feet over a given area at a specific time (the valid time). The GFA is designed primarily to meet the needs of general aviation and regional air carriers.[27]

GFAs have a validity period of 12 hours and are amended by significant meteorological information (SIGMET) or new information (AIRMET[28]), or are superseded by a forecast with a more recent valid time.[29]

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27 NAV CANADA: Aviation Weather Web Site / User's Guide, Section 3.2.7, "Graphic Forecast Area (Graphical FA)," at https://flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=weather-products&NoSession=&TypeDoc=user-guide&Langue=anglais#gfa (last accessed on 01 August 2017).

28 AIRMET refers to "[s]hort-term meteorological information intended primarily for aircraft in flight, to notify pilots of potentially hazardous weather conditions not described in the current area forecast and not requiring a SIGMET." (Source: Transport Canada, *Glossary for Pilots and Air Traffic Services Personnel* [19 July 2012].)

29 Transport Canada, TP 14371E (2016-1), *Aeronautical Information Manual,* section MET 1.3.6.

Table 5 provides definitions of some of the terms used in GFAs.

Table 5. GFA definitions

Abbreviation	Term	Definition
BKN	Broken	5–7 oktas*
XTNSV	Extensive	Greater than 50% spatial coverage
PTCHY	Patchy	26–50% spatial coverage
LCL	Local	25% or less spatial coverage
MDT ICG	Moderate icing	The rate of accumulation is such that even short encounters become potentially hazardous, and use of de-icing or anti-icing equipment or diversion is necessary.**
SVR ICG	Severe icing	The rate of accumulation is such that de-icing or anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.**
MXD ICG	Mixed icing	Rime and clear icing occurring at the same time.

* 1 okta of cloud covers one eighth of the sky.

** Transport Canada, TP 14371E (2016-1), *Aeronautical Information Manual,* section MET 2.4.

Appendix B shows the 2 graphics of the Ontario–Quebec GFA valid at 0700, depicting the following conditions that were forecast over the northwestern Ontario region:

- Clouds and weather (issued at 0651): broken clouds based at 3000 feet ASL topped at 6000 feet ASL; patchy ceilings based at 600 to 1200 feet AGL; and local visibility 2 sm with light snow, light freezing drizzle, mist, and ceilings at 300 feet AGL.
- Icing, turbulence, and freezing level (issued at 0653): Freezing level at the surface; no moderate or severe turbulence; patchy moderate mixed icing between 3000 and 6000 feet ASL; and local moderate mixed icing from the surface to 3000 feet ASL due to freezing drizzle.
- No SIGMET or AIRMET was issued following the GFA.

1.7.2.5 Pilot reports

Pilots periodically make reports of weather conditions that are then disseminated for use by other pilots. On 11 December 2015, the first pilot report in northwestern Ontario was made after the accident.

1.7.2.6 Automated supplementary enroute weather predictions

As described by NAV CANADA,

> The Automated Supplementary Enroute Weather Predictions (ASEP) graphic products are computer generated directly from processed numerical forecast data with no human intervention or alteration of the displayed products.[30]

Because the products are custom-produced according to user inputs, they are not archived and cannot be produced retroactively.

The ASEP icing graphic product comprises 2 graphics depicting the vertical and horizontal distribution of predicted icing along the proposed flight route. Icing type or intensity cannot be predicted.[31]

1.7.3 Enroute weather experienced by another Wasaya Cessna 208B flight

Another Wasaya Cessna 208B, C-FKAD operating as WSG128, departed from CYPL at 0848 on a VFR flight to the northeast. The aircraft was prohibited from flight in known or forecast icing conditions. The pilot had completed the Cessna Cold Weather Operations course in November 2015.

During the pre-flight preparation, the pilot checked METARs and TAFs for CYPL and several other airports to the northeast. The pilot reviewed the Ontario–Quebec GFA, and noted that it forecasted local icing due to freezing drizzle. The pilot's assessment of the weather information was that the flight could be conducted under VFR, that the forecasted local icing was isolated, and that there was a chance that icing would be encountered during the flight.

There was no precipitation at CYPL during the pre-flight preparations. Before engine startup, the pilot conducted a tactile check of the upper wing surface and determined that there was no contamination.

After takeoff, the pilot observed that the sky condition at CYPL was ragged, with scattered clouds based from 400 to 700 feet AGL; there were ragged, broken, and overcast layers above, with visibility of 5–10 sm and visible areas of precipitation. The pilot decided that flight below the cloud base was undesirable, and the flight continued climbing, eventually reaching a peak altitude of about 4400 feet ASL.

During the climb, the aircraft was flying through mist and began slowly accumulating trace icing on the windshield and leading edges as the flight cleared the MF zone to the northeast of CYPL. As the climb continued, the pilot had intermittent visual contact with the surface

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30 NAV CANADA: Aviation Weather Web Site / User's Guide, Section 3.3, "ASEP Products," at https://flightplanning.navcanada.ca/cgi-bin/CreePage.pl?Page=asep-products&NoSession=&TypeDoc=user-guide&Langue=anglais#asep (last accessed on 01 August 2017).

31 Ibid., Section 3.3.7, "Icing.".

while the flight was in and out of cloud, intermittently operating in instrument meteorological conditions. The pilot activated the windshield anti-icing panel and propeller anti-icing boots, and periodically increased and reduced propeller speed to assist with ice removal. The leading-edge de-icing boots were not operated during the climb. The pilot controlled the aircraft manually, with the autopilot off.

By the time the flight was 15 nm northeast of CYPL, about 5–6 minutes after initially encountering icing, the windshield was opaque with ice except on the heated portion of the anti-icing panel. The pilot could feel propeller vibration and ice shedding from the propeller, the leading edges had accumulated less than a quarter of an inch of ice, and airspeed had decreased by 5–10 knots. No controllability problems were observed. The pilot decided that the best course of action was to return to CYPL. He therefore turned back and commenced a descent. This was about 2 minutes after WSG127 reported that it was clear of the MF zone.

Shortly after turning around, the pilot of WSG128 operated the leading-edge de-icing boots once, when there was about a quarter of an inch of ice accumulation. The pilot acquired visual contact with CYPL about 5 nm from the airport, and used 20° of flap for landing. During the landing, the windshield was opaque with ice accumulation, with good visibility through the heated anti-icing panel. There was ice on the propeller after landing.

1.7.4 Current Icing Product

The Current Icing Product (CIP) is produced by the U.S. Aviation Weather Center and is available for the 48 contiguous United States and much of Canada. The CIP is composed of "computer-generated three-dimensional analyses of information related to the likelihood of encountering icing conditions" and "represents the latest analysis of potential icing regions."[32] It is available to pilots for pre-flight planning through the U.S. Aviation Weather Center website, and consists of graphics depicting probability and severity of icing at selected altitudes.

Archives of the CIP graphics for 11 December 2015 were not available. The U.S. National Center for Atmospheric Research conducted a CIP reanalysis for 11 December 2015 at 0908 (appendices C and D).

The CIP icing probability graphics depict icing probability in the CYPL area beginning at approximately 1500 feet ASL, increasing to 60% probability between 2500 and 5000 feet ASL, and decreasing to 20% between 5000 and 6000 feet ASL.

The CIP icing severity estimations are

> roughly based on the accretion rate of ice on an airplane, and the levels are determined by the time it would take for an airfoil to accrete ¼ [inches of] ice: trace, 1 h; light, 15 min-1 h; moderate, 5-15 min; and severe < 5 min. The rates are, in turn, estimated from the amount of supercooled liquid water expected

32 U.S. Aviation Weather Center, "ADDS Icing Help," at https://aviationweather.gov/icing/help (last accessed 01 August 2017).

> with a nominal drop diameter of 15 microns [μm], and are further tuned by nearby pilot reports of encountered severity. These are relative values and the use of which should take into account the airframe and the level of icing protection provided by the aircraft.[33]

The CIP icing severity graphics (Appendix D) depict the icing severity potential in the CYPL area as trace to light icing conditions from 1500 to 2500 feet ASL and as light icing conditions from 2500 to 5000 feet ASL.

1.7.5 Pickle Lake Airport upper-air meteorological conditions

Environment Canada conducts radiosonde upper-air soundings at CYPL. Radiosondes are weather instruments that are released into the atmosphere by use of weather balloons. As the weather balloon rises, the radiosonde collects data, such as wind speed, wind direction, temperature, and humidity at different altitudes. This information is used by meteorologists and is not available to pilots for pre- or in-flight use.

The information from the observation on 11 December 2015 at 0700 was plotted on a Skew-T Log-P diagram[34] from the surface to 18 000 feet using RAOB[35] software (Appendix E).

The sounding icing algorithm supported a moderate-to-high risk of moderate-to-severe icing conditions in the clouds and precipitation from the surface to the cloud tops near 5000 feet ASL. Table 6 shows the types and probability of icing conditions that were determined from the sounding data.

Table 6. Probability and type of icing conditions at CYPL, 11 December 2015, 0700 EST

Height (feet ASL)	Temperature (°C)	Dew point (°C)	Icing type and intensity	Icing probability (%)
1224 (surface)	−4.7	−6.1	Moderate rime	82
2153	−6.9	−8.0	Severe clear	92
4299	−11.9	−12.0	Moderate clear	93
4447	−12.3	−13.2	Trace clear	68
4902	−8.3	−10.9	Trace rime	61
4963	−8.3	−13.3	Trace rime	22

1.7.6 Ontario–Quebec graphical area forecast for 09 and 10 December 2015

During the 2 days before the accident, the northwest region of Ontario had experienced low ceilings and visibility, with freezing fog and freezing drizzle.

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33 Ibid.

34 A Skew-T Log-P diagram is a standard meteorological plot using temperature and the logarithmic of pressure as coordinates, used to display winds, temperature, dew point, and various indices to define the vertical structure of the atmosphere.

35 RAOB is an interactive sounding analysis program developed by Environmental Research Services in Matamopras, Pennsylvania.

Appendix F shows 2 graphics from the Ontario–Quebec GFA valid at 0700 on 09 December 2015, depicting the following conditions, which were forecasted over the northwestern Ontario region:

- Clouds and weather (issued at 0631): local visibility 4 sm with light snow, patchy ceilings based at 400 feet AGL, and local visibility ½ sm with freezing fog.
- Icing, turbulence, and freezing level (issued at 0633): freezing level at the surface; no moderate or severe turbulence from the surface to flight level 210;[36] moderate mixed icing from 2500 to 5000 feet ASL, with local moderate mixed icing from the surface to 2500 feet ASL due to freezing drizzle.

Appendix G shows 2 graphics from the Ontario–Quebec GFA valid at 0700 on 10 December 2015, depicting the following conditions that were forecasted over the northwestern Ontario region:

- Clouds and weather (issued at 0641): broken clouds based at 3000 feet ASL and topped at 5000 feet ASL with visibility greater than 6 sm; local visibility 2 sm with light snow; extensive ceilings at 300 to 800 feet AGL with local visibility ¾ sm in mist and light freezing drizzle.
- Icing, turbulence, and freezing level (issued at 0643): freezing level at the surface; no moderate or severe turbulence; moderate mixed icing from 3000 to 5000 feet ASL, with local moderate mixed icing from the surface to 3000 feet ASL due to freezing drizzle.

1.8 Aids to navigation

WSG127 navigation was based on the Garmin GTN 750 global positioning system (GPS) installed in C-FKDL. No issues or outages were reported.

1.9 Communications

WSG127 communication with NAV CANADA Air Traffic Services was conducted with the Thunder Bay Flight Service Station on the CYPL MF of 122.2 MHz. There were no problems with voice communications on this frequency.

The pilot of WSG128, returning to CYPL after encountering icing, established radio contact with WSG127 on 126.7 MHz and proposed a different frequency but was unable to establish contact on the second frequency to advise of the flight's return to CYPL because of the icing conditions. The pilot was unable to continue attempting contact because of the need to communicate with the Thunder Bay Flight Service Station on the CYPL MF and to prepare for landing. The pilot contacted the Wasaya operations coordinator at CYPL to indicate the icing conditions and the return of WSG128. The operations coordinator subsequently

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[36] Flight level 210 (21 000 feet, mean sea level) is the altitude expressed in hundreds of feet indicated on an altimeter set to 29.92 inches of mercury. Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* (TC AIM), (02 April 2015), General, 5.1 Glossary of Aeronautical Terms.

attempted to contact WSG127 on the company frequency to pass on the report of icing and to advise that WSG128 was returning.

The ISAT-100 satellite flight tracking system installed in C-FKDL provides the capability for pilots to exchange text messages with Wasaya flight followers. There were no text messages sent during the flight of WSG127. The ISAT-100 satellite flight tracking system also provides status messages to flight followers; at 0910, Wasaya flight followers received a message that the status of WSG127 was "Engines-Stop" and "Wheels-On."

1.10 Aerodrome information

CYPL is a certified airport operated by the Government of Ontario. The airport has 1 asphalt runway, designated 09/27, which is 4921 feet long and 100 feet wide.

1.11 Flight recorders

C-FKDL was not equipped with a flight data recorder or a cockpit voice recorder, and neither was required by regulation.

Numerous TSB aviation investigation reports have noted that investigators were unable to determine the reasons for an accident because of the absence of on-board recording devices.[37] The benefits of recorded flight data in aircraft accident investigations are well known and documented.[38]

In 2013, following its investigation into a loss of control/ in-flight breakup occurrence northeast of Mayo, Yukon, in March 2011 (TSB Aviation Investigation Report A11W0048), the TSB found that if cockpit or data recordings are not available to an investigation, the identification and communication of safety deficiencies to advance transportation safety may be precluded. It further concluded that, when an accident occurs, recordings from lightweight flight recording systems provide useful information to the investigation to enhance the identification of safety deficiencies. Therefore, the Board recommended that

> the Department of Transport work with industry to remove obstacles to and develop recommended practices for the implementation of flight data monitoring and the installation of lightweight flight recording systems by commercial operators not currently required to carry these systems.
>
> **TSB Recommendation A13-01**

In response to Recommendation A13-01, in 2013, TC conducted discussions with industry and completed a risk assessment to evaluate alternate approaches to flight data monitoring (FDM) in Canada. Following the risk assessment, TC decided to proceed with the development of an Advisory Circular in 2015–16 to describe recommended practices regarding FDM programs. In January 2015, TC was planning to conduct focus groups to

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37 TSB aviation investigation reports A01W0261, A02W0173, A03H0002, A05W0137, A05C0187, A06W0139, A07Q0063, A07W0150, A09A0036, A09P0187, and A10P0244.

38 TSB Aviation Investigation Report A11W0048.

identify obstacles within TC's mandate and make recommendations for mitigation of those obstacles with respect to the installation of lightweight flight recording systems for commercial operators not required to carry these systems. In November 2015, TC was planning to prepare an issue paper providing factual information on FDM, as well as benefits, costs, and challenges to increasing the use of FDM. TC was also planning to revisit the risk assessment conducted on FDM and recommend options to the Minister.

In January 2017, TC indicated it would conduct a focus group later that year, including representatives from the industry and the TSB, to evaluate the challenges and benefits associated with widespread installation of lightweight multi-function recording devices in small aircraft.

In its March 2017 reassessment of Recommendation A13-01, the TSB stated that the focus group has been planned since 2013. Until the focus group reaches conclusions as to the challenges and benefits associated with the installation of lightweight multi-function recording devices in small aircraft, and TC provides the TSB with its plan of action moving forward following those conclusions, it is unclear when or how the safety deficiency identified in Recommendation A13-01 will be addressed. Therefore, the response to Recommendation A13-01 was assessed as Unable to Assess.

1.12 Wreckage and impact information

WSG127 collided with trees and terrain on the southeast side of Tarp Hill, Ontario, in a forested area at coordinates 51°36'31.40" N, 90°9'34.82" W, at an elevation of 1460 feet ASL. The forest was composed mainly of coniferous trees up to about 50–60 feet tall and up to 14 inches in diameter, as well as of similarly sized deciduous trees.

The initial impact point was the top of a tree about 60 feet above ground. The aircraft descended at a pitch angle of about 40° through trees along a track of about 160° magnetic (M). It struck a number of trees as it descended, causing several to break off at about 20–30 feet above the ground. The distance from the first tree strike to where the nose of the aircraft came to rest was 82 feet. The aircraft collided with the terrain in a wings-level attitude with greater than 30° nose-down pitch.

The fuselage came to rest on a heading of about 198°M against and on top of trees (Figure 3).

All of the damage to the aircraft was attributable to impact forces. All of the flight control surfaces and major structural components were found with the wreckage.

The cockpit volume was substantially compromised by impact forces, with the firewall and instrument panel displaced rearward and the cargo bulkhead displaced forward.

The ELT antenna had separated from its external mount and was found on the ground on the left side of the fuselage. An examination determined that the antenna cable had been pulled out of the connectors at the ELT and at the inside of the fuselage antenna mount.

Figure 3. Left front view of wreckage

Examination of the airframe wreckage at the crash site revealed accretion of ice about five sixteenths of an inch thick on the outside air temperature probe (Figure 4), antennas (Figure 5), and other protruding components. There was residual ice on the de-icing boots on the vertical stabilizer (Figure 6), horizontal stabilizer (Figure 7), and right wing (Figure 8), indicating that the boots had been operated after in-flight accretion of ice.

Figure 4. Ice on the outside air temperature probe

Figure 5. Ice on an antenna on the right side of the vertical stabilizer

Figure 6. Ice on the right side of the vertical stabilizer

Figure 7. Ice on the leading edge of the left horizontal stabilizer

Figure 8. Ice on the leading edge of the right wing outboard section

The investigation determined that the engine had been producing power at impact; the power turbine and compressor turbine blades were intact. The first-stage reduction gearbox coupling had sheared off the first-stage carrier, with signs of rotation. The starter generator quill shaft was fractured, with evidence of torsional failure. Disassembly of the engine determined that the power and compressor turbines, as well as the engine casing, exhibited signs of substantial power at impact. The propeller damage was characteristic of being under power at impact.

The cargo was found mainly in the cabin area, with some lighter pieces ejected from the cabin through the ruptured fuselage sides. The snowmobile remained secured to the floor with tie-down straps behind the right cargo bulkhead; however, the cabin floor structure had buckled and broken, allowing the snowmobile to move forward.

The King KFC-150 autopilot controller was destroyed by impact forces. The system does not employ non-volatile memory. The investigation could not determine whether the autopilot had been used by the pilot of WSG127 at any time during the flight.

Examination of selected wreckage components by the TSB Engineering Laboratory revealed the following:

- A broken propeller blade tip was determined to have fractured in overstress, and a semi-cylindrical dent in the blade tip showed signs of material transfer from an object made of a stainless steel alloy.

- The propeller tachometer needle was positioned at 1775 rpm. It was determined that 1775 rpm would have been a valid reading at the time that the signal from the associated tachometer generator was lost during the impact sequence.
- Indications on the airspeed and vertical speed instruments could not be determined.
- All of the annunciator lamps examined were likely in an "off" state, with the exception of the FUEL SELECT OFF annunciator. The filaments of the FUEL SELECT OFF annunciator displayed characteristics of lamps that were illuminated at impact. The annunciator had likely illuminated as a result of disruption and shorting of the wiring associated with this circuit during the impact sequence.
- The left-seat flight command indicator had operated normally, and no anomalies were noted that would have precluded an accurate display of pitch and roll. As tested, the instrument accurately displayed pitch and roll information within a range of −30° to +30° pitch and 60° left to right roll.
- The right-seat attitude indicator was likely functioning at the time of impact.
- The BOOT PRESS switch on the de-icing control panel had operated normally, and there was nothing to indicate that it would not have performed as designed at the time of the occurrence.
- No fault was found with the pneumatic de-icing timer, which controls the de-icing control valve solenoids. It was likely operational at the time of the occurrence.
- The 3 de-icing ejector-flow–control valve solenoids were likely operational at the time of the occurrence. These valves supply air to the leading-edge de-icing boots.
- All 3 leading-edge de-icing pneumatic pressure switches activated within the specified pressure range.
- The stall-warning circuit breaker was recovered in an open state; the examination could not determine its state before the occurrence, or when it had changed state.
- All data stored in the ISAT-100 satellite flight tracking system's memory were recovered by the TSB Engineering Laboratory. Data pertaining to WSG127 on 11 December 2015 commenced at 0903:00, with a capture rate of one data point every 5 seconds. The investigation could not determine why the data commenced in flight rather than during takeoff. The last data point was captured at 0909:51.
- The Garmin GTN750 GPS did not store flight plan, waypoint, track, or history data.

1.13 Medical and pathological information

The investigation determined that there was nothing to indicate that the pilot's performance was degraded by physiological factors.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 Occupant restraint system

The pilot occupied the left seat and used the 4-point lap-and-shoulder harness restraint system attached to the primary airframe structure. During the accident, the pilot remained in the seat throughout the crash sequence. The cockpit volume was substantially reduced during the accident, resulting in non-survivable injuries.

1.15.2 Emergency locator transmitter

Following the crash, no ELT signal from C-FKDL was detected on either 121.5 MHz or 406 MHz frequencies, making it more difficult for SAR personnel to find the aircraft. Data recovered from the ELT indicated that the G-switch had closed during the crash and that the ELT had operated until it was turned off by SAR technicians. The ELT was tested and found to be operational.

Research has identified deficiencies in the design and certification of ELTs. In 1990, a National Aeronautics and Space Administration (NASA) study determined

> that 88% of the [ELT] failures are crash related, i.e., "G" switch, fire damage, impact damage and antenna broken or disconnected, which reflects a requirement for ELTs and antennas which are more crash damage resistant.[39]

A 2009 Canadian study examined reasons for ELT failures during aircraft incidents related to impact and human factors. The study determined that impact-related damage accounted for 92% of all failures among the occurrences examined. As a result, the report concluded that the "greatest opportunity for improvement is to address ELT failure due to crash impact" and identified survivability of antenna and connecting coaxial cable as possible areas for improvement.[40]

More recent studies, conducted by the Canadian Mission Control Centre and the Australian Transport Safety Bureau (ATSB) have found that impact-related damage (i.e., fire damage,

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39 B. J. Trudell and R. R. Dreibelbis, *Current Emergency Locator Transmitter (ELT) Deficiencies and Potential Improvements Utilizing TSO-C91a ELTs*, NASA Contractor Report 4330 (Landover, MD: National Aeronautics and Space Administration, 1990), p. 4, at https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910001651.pdf (last accessed on 01 August 2017).

40 J. Keillor, et al., *Emergency Locator Transmitter (ELT) Performance in Canada from 2003 to 2008: Statistics and Human Factors Issues*, Technical Report DRDC Toronto TR 2009-101 (Defence Research and Development Canada, September 2009), part 5.1.1, p. 30, at http://cradpdf.drdc.gc.ca/PDFS/unc90/p532159.pdf (last accessed on 01 August 2017).

impact damage, broken/disconnected antenna, and water damage) is responsible for the majority of non-activations.[41,42]

In 2016, following its investigation into a May 2013 controlled flight into terrain in Moosonee, Ontario,[43] the TSB found that current standards for ELT system design do not require a crashworthy antenna system. It further concluded that there is a risk that potentially life-saving SAR services may be delayed if an ELT antenna is damaged during an occurrence. Therefore, the Board made the following recommendations:

> The International Civil Aviation Organization establish rigorous ELT system crash survivability standards that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-02**
>
> The Radio Technical Commission for Aeronautics establish rigorous ELT system crash survivability specifications that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-03**
>
> The European Organisation for Civil Aviation Equipment establish rigorous ELT system crash survivability specifications that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-04**
>
> The Department of Transport establish rigorous ELT system crash survivability requirements that reduce the likelihood that an ELT system will be rendered inoperative as a result of impact forces sustained during an aviation occurrence.
>
> **TSB Recommendation A16-05**

International collaborative work is underway to improve ELT specifications for antenna, cabling, and crash survivability. In December 2016 and February 2017, the TSB assessed responses to these recommendations as Satisfactory Intent.

1.15.3 Search and rescue

Wasaya had equipped its fleet with ISAT-100 satellite flight tracking systems, and Wasaya flight-following staff were aware that WSG127's status was abnormal within minutes of the accident. The company began a communications search for WSG127 at about 0921. At 0950, Wasaya notified the Joint Rescue Coordination Centre in Trenton that the flight was overdue

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41 Canadian Mission Control Centre (CMCC) [slide presentation], 2014 CMCC Stats Report (undated), Reasons for Non-Activation.

42 Australian Transport Safety Bureau, Aviation Research Investigation AR-2012-128, *A review of the effectiveness of emergency locator transmitters in aviation accidents* (21 May 2013).

43 TSB Aviation Investigation Report A13H0001.

and provided the last known position of WSG127 from the ISAT-100 satellite flight tracking system.

A SAR flight located the crash site visually at 1340, but weather conditions prevented air access to the site. SAR technicians reached the remote site by ground at 2250 and found the pilot without vital signs.

1.16 Tests and research

1.16.1 WSG127 flight data analysis

The TSB Engineering Laboratory conducted an analysis of meteorological information and the recorded data for flight WSG127 from the ISAT-100 satellite flight tracking system. The time, position, and height data from the GPS were used to determine the flight path of the aircraft. These were combined with geospatial data (appendices H and I).

Additionally, the GPS data were used to calculate ground speed, track, and vertical speed. Atmospheric data (wind, temperature, pressure) from the 0700 radiosonde sounding at CYPL were used to estimate calibrated airspeed. Further analysis estimated the aircraft attitude (heading, roll, and pitch) and accelerations (vertical and longitudinal). These data and estimates are plotted in appendices J and K.

At the beginning of the recorded data, WSG127 was climbing at about 800 fpm at an estimated 104 knots calibrated airspeed (KCAS), decreasing to as low as 98 KCAS. At 0903:32, WSG127 commenced a descent from 2800 feet ASL to about 2700 feet ASL, and the estimated airspeed increased to 120 KCAS. It then climbed again at about 600 fpm, with the estimated airspeed decreasing to and stabilizing at 110 KCAS.

Subsequently, the climb was shallower, with the vertical speed averaging about 400 fpm between 0904 and 0907:34. The estimated airspeed was initially 110 KCAS, gradually decreasing to 102 KCAS at 0907:34. From 0907:34 to the top of the climb at 0908:41, the rate of climb averaged about 250 fpm, with the estimated airspeed decreasing further to 99 KCAS. Under these conditions, the angle of attack was estimated to be relatively high in the flaps-up configuration.

Beginning at about 0908, there were 2 oscillations in estimated airspeed within about 45 seconds. Both of these occurred during brief increases in climb rate and resulted in the estimated airspeed decreasing to as low as 98 KCAS.

At about 0908:45, the climb ceased and transitioned into a shallow descent. It could not be determined whether the pilot had commanded this descent. The descent remained shallow for about 15 seconds, and then increased rapidly to 7000 fpm, with the estimated airspeed increasing to about 140 KCAS (Appendix K, Event 1). The analysis indicated that the aircraft rolled to the right (about 45° right bank) and pitched nose down, reaching about 25° nose-down pitch, with the aircraft ground track abruptly turning about 120° to the right.

The rapid descent following Event l was arrested by about 2700 feet with a pull-up manoeuvre of about 1.5*g*. The resulting brief climb toward 2800 feet led into Event 2 (Appendix K, Final 2 minutes), during which the airspeed decreased rapidly from about 140 KCAS to 60–70 KCAS.

Almost immediately, the aircraft began to descend rapidly, exceeding 6000 fpm before the data ended at 0909:51, when the estimated airspeed had increased to 90 KCAS. Analysis of Event 2 suggested a right roll and yaw, and a nose-down pitch greater than 30°. Unlike Event l, Event 2 did not involve an abrupt large turn.

The large and rapid decay in airspeed leading into Event 2 indicated a large increase in drag compared with an uncontaminated aircraft in the flaps-up configuration. Greater than normal airframe drag would also be consistent with the relatively poor climb performance earlier in the flight.

1.16.2 TSB Engineering Laboratory reports

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

- LP288/2015 NVM [Non-Volatile Memory] Recovery – ISAT 100
- LP289/2015 NVM Recovery – GPS
- LP008/2016 Instruments and Annunciator Panel Analysis
- LP025/2016 Broken Blade Tip Examination
- LP027/2016 Circuit Breaker Analysis
- LP089/2016 De-Icer Timer and Solenoids Analysis
- LP090/2016 Pressure Switches Analysis
- LP094/2016 Instruments Analysis
- LP155/2016 GPS Data Analysis

1.17 Organizational and management information

1.17.1 Wasaya

Wasaya is based at Thunder Bay Airport (CYQT), in Thunder Bay, Ontario, and operates under an air operator certificate issued by TC, which authorizes the types of services listed in the certificate. Wasaya operates a fixed-wing fleet under subparts 705, 704, and 703 of the CARs, providing scheduled passenger service, charters, and cargo operations to the northwest region of Ontario. The company operates from its main base at CYQT and from sub-bases at CYPL, Red Lake Airport (CYRL), and Sioux Lookout Airport (CYXL). On 11 December 2015, its fleet was as shown in Table 7.

Table 7. Wasaya fleet composition on 11 December 2015

Aircraft type	Number of aircraft	CARs subpart
Beechcraft 1900D	7	704
Cessna 208B	5	703
Hawker Siddeley HS748	3	705
Pilatus PC12/45	3	703
De Havilland DHC-8-100	1	705

Wasaya's director of operations (DO) is the company operations manager, and is responsible for control of flight operations and operational standards for all airplanes operated.[44] The chief pilot, flight attendant manager, system operations control centre (SOCC) manager, station managers at all bases, and dangerous goods supervisor report to the DO.

Wasaya maintains current information on the location of the company's aircraft at its main base and sub-bases, and can communicate with flights by radio or by text messaging through the ISAT-100 satellite flight tracking system.

1.17.1.1 Operational control

Operational control refers to "the exercise of authority over the formulation, execution, and amendment of an operational flight plan in respect of a flight."[45] Wasaya uses a Type C operational control system, which is under the control of the DO. The Type C system delegates operational control to the pilot-in-command (PIC) of a flight, while the DO retains responsibility for the day-to-day conduct of flight operations.[46]

Wasaya's flight-following system monitors ongoing operations through the SOCC and station managers, enabling the company to amend or cancel flights and to make other operational decisions.

Wasaya also conducts a daily operations teleconference at 0810 each morning, which reviews completed operations of the previous day and planned operations for the current day. Some of the factors taken into account are existing and forecasted weather, aerodrome conditions, fleet airworthiness, planned passenger and cargo loads, and potential issues over the next 48 hours. The teleconference assesses whether planned flights should proceed, be delayed, or be cancelled. Station managers and the SOCC then make local or system-wide revisions to the daily flying plan.

The Wasaya operations teleconference on 11 December 2015 had typical attendance, with about 20 participants from bases, SOCC, cargo and passenger services, maintenance, safety

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44 Wasaya Airways Limited Partnership, *Company Operations Manual*, Revision 2 (19 December 2014), section 1.3.2.

45 Transport Canada, *Canadian Aviation Regulations* (CARs) Standard 725.20: Operational Control System, General.

46 Wasaya Airways Limited Partnership, *Company Operations Manual*, Revision 2 (19 December 2014), section 2.1.1, p. 2.1-1.

management system (SMS), and operations management. The conference followed the same format as previous such conferences. The weather was reviewed, and it was assessed as similar to conditions during the previous 2 days, with snow and low ceilings in the area of operations.

1.17.1.1.1 Flight authorization

All Wasaya flights require authorization by the duty managers, who have been delegated this authority by the DO.[47] At CYPL, flights were authorized by the station manager, who would assign aircraft and crew members to conduct cargo and passenger flights. The station manager would post flight details on wall boards and computer monitors in the CYPL operations offices to show authorized flights.

1.17.1.1.2 Pilot self-dispatch

Under the Type C operational control system, all Wasaya flights are self-dispatched and released by the PIC.

Wasaya provides pilots with operational information to enable them to make dispatch and release decisions. Computers are provided to obtain weather information and notices to airmen and to complete pre-flight documents. Other resources available to assist pilots in decision making include company and aircraft manuals, base operations coordinators, station managers, training pilots, and the chief pilot. The final decision to release the flight is made by the pilot. If a flight is not released, the station operations coordinator is advised so that the planned flying schedule can be revised.

The PIC is responsible for preparing the operational flight plan (OFP), which must include an FDC form, a weight-and-balance form, and a manifest. The signature on the FDC indicates that the PIC has approved the OFP, that the weight-and-balance calculation has been completed, and that the weight and the centre of gravity are within limits.[48,49] PICs are required to carry the original OFP on board and leave a duplicate copy at the point of departure.

The FDC specifies "the conditions under which the flight or series of flights are to be conducted."[50] The FDC for WSG127 showed that the flight was planned to be conducted under VFR, under company flight-following, at an altitude of 5500 feet ASL.[51] The pilot had signed the form, and it was recovered from the crash site. A duplicate copy had been left with the CYPL operations coordinator.

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47 Ibid., section 2.2, p. 2.2-1.

48 Ibid., section 2.3.5.1, p. 2.3-3.

49 Ibid., section 2.6.2, p. 2.6-1.

50 Ibid., section 2.3.5.2, p. 2.3-3.

51 Forecast and actual weather at CYPL at 0800 indicated overcast ceiling at 1500 feet AGL and 1000 feet AGL, respectively.

A copy of the cargo manifest for WSG127 was recovered from the crash site, and a duplicate copy had been left with the CYPL operations coordinator.

1.17.1.2 Weight and balance control

The Wasaya COM states, "The load control form is to be completed for all flights, unless the pilot loads or supervises the loading of the aircraft."[52] Appendix L shows the Wasaya load control form provided to load planners and loading crews for their use, referred to here as the "load distribution form."

Wasaya's aircraft loading procedures are normally conducted as follows. The cargo department determines the freight that is to go on a flight and prepares a manifest. The station loadmaster then takes the cargo manifest, physically inspects the cargo, and prepares a load plan that specifies how the cargo is to be loaded on the aircraft. The loadmaster then uses a weight-and-balance slide rule or spreadsheet to confirm that the cargo can be loaded within weight-and-balance limits. If the load plan is outside of limits, the loadmaster will adjust the load plan to bring it within limits. The load plan is documented on the load distribution form, which is then taken to the aircraft and used to load the cargo. The load distribution form is given to the pilot so that he or she may complete the weight-and-balance form.[53]

After the accident, Wasaya found that loading crews at its CYRL base were using the load distribution forms properly for flights on all aircraft types, but that, at CYPL, the load distribution forms were being prepared for flights on aircraft types other than Caravans. As a result, at the time of the accident, CYPL crews loading Caravans were not using the load distribution form (Appendix L), and no load distribution form was found for WSG127.

A weight-and-balance form must be completed for every flight before departure. The original is used by the flight crew, and a duplicate copy must be left at the point of departure.[54] Appendix M shows the Wasaya weight-and-balance form (also referred to on the form as a "load control form") provided for use by its Caravan pilots. While this form assists in calculating the aircraft weight, it does not provide a space to record the centre of gravity. As well, although the form includes maximum weights for ramp, takeoff, and landing, it does not include the maximum weight for aircraft certified to fly in icing conditions.

Wasaya provides guidance to pilots for completion of the weight-and-balance calculation. For aircraft types other than the Cessna 208B, the COM required the use of aircraft-specific weight-and-balance forms or slide rules as a means of making the calculation. For the

52 Wasaya Airways Limited Partnership, *Company Operations Manual*, Revision 2 (19 December 2014), section 2.3.5.7, p. 2.3-4.

53 Ibid., section 2.6.1, p. 2.6-1.

54 Ibid., section 2.3.5.3, p. 2.3-3.

Cessna 208B, the COM did not specify the means by which pilots were to calculate a weight and balance; the COM stated that the aircraft

> is loaded in accordance with the manufacturers [*sic*] procedures as outlined in the AFM which state that the load is to be distributed in accordance with the load lines on the interior cabin walls.[55]

As with its other aircraft types, Wasaya provided its Caravan pilots with Cessna 208B-specific slide rules and computer spreadsheets to perform weight-and-balance calculations.

No weight-and-balance form (Appendix M) prepared by the pilot for WSG127 was found either at the crash site or at the Wasaya CYPL operations room. The pilot had flown C-FKDL regularly during the 9-day period from 02 to 10 December 2015, and records for these flights all included a Wasaya weight-and-balance form signed by the pilot.

1.17.1.3 Safety management system

1.17.1.3.1 General

Wasaya was required by regulation to establish and maintain an SMS for its operations under Subpart 705 of the CARs and for its approved maintenance organization.[56] The company had previously established an SMS and was in the maintenance phase of SMS operation. The SMS at Wasaya was applicable to the entire company.[57] The scope of the investigation regarding Wasaya's SMS was limited to items involving Caravan equipment installation and icing operations.

1.17.1.3.2 Flight in known or forecast icing conditions risk assessment

On 16 January 2015, as part of its SMS, Wasaya conducted a risk assessment[58] regarding "installation of complete C208B pneumatic de-ice system to allow flight into known or forecast icing conditions." Hazards described included the following:

- Aircraft may operate outside of capabilities as a result of ice accumulation.
- Operation of a fleet with mixed configurations could result in Caravans being dispatched into known or forecast icing conditions without being equipped for those conditions.
- Current Cessna 208B pilots have not previously operated in known or forecast icing conditions.

The initial risk level was assessed as moderate. However, the SMS database software used by Wasaya in January 2015 did not retain the probability or severity categories used to obtain

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55 Ibid., section 2.6.2, p. 2.6-1.

56 *Canadian Aviation Regulations* (CARs), paragraph 107.01(1)(b).

57 Wasaya Airways Limited Partnership, *Safety Management System Procedures Manual*, Revision 8 (15 May 2015), p. 9.

58 Wasaya SMS Risk Assessment Worksheet, 16 January 2015.

the risk assessment rating of moderate. The risk matrix shows that the likely combination of categories for a moderate-risk rating was either “unlikely probability” and “moderate severity,” or “possible probability” and “minor severity.”

The risk assessment proposed risk-control strategies in the following areas:

- review of and compliance with the POH and the FAA-Approved AFM Supplement S1: *Known Icing Equipment*;
- revision of the training program to incorporate new requirements;
- amendment of SOPs before Cessna 208B flights in known or forecast icing conditions;
- consultation with station managers regarding aircraft capabilities and limitations in icing conditions;
- briefing of station aircraft maintenance engineers on new maintenance requirements; and
- continuation of current maintenance practices for de-icing boot installation and upkeep.

The post-mitigation risk level was assessed as moderate and was rated as acceptable.

The short-term action proposed was to review installed equipment required for flight in known icing conditions and to assess changes needed to the SOPs. The long-term action proposed was to amend the SOPs and to assess operation of newly installed equipment. The proposed date for follow-up review of implementation was 27 May 2015.

In May 2015, the Wasaya SMS database did not automatically create follow-up reminders.

1.17.1.3.3 Follow-up to January 2015 risk assessment

On 26 September 2015, Wasaya completed installation of equipment on C-FHWA, one of its 5 Cessna 208B aircraft, to certify the aircraft for flight in known icing conditions. This aircraft was employed as part of a trial for the company to assess whether the installation would offer enhanced ability to deliver passengers or cargo.

At the time of the accident, the trial period had just started, and the installation had not yet been considered for the company’s remaining 4 Cessna 208B aircraft, which remained prohibited from flight in known or forecast icing conditions.

As part of its risk-control strategies, Wasaya provided its Caravan pilots with access to the Cessna Cold Weather Operations Course and the Cessna 208B POH/AFM Supplement S1: *Known Icing Equipment*. The Cessna Cold Weather Operations Course is a means of compliance with a training limitation specified in Supplement S1.[59]

On 11 December 2015, the Wasaya C208 SOPs had not yet been amended to take into account the certification of C-FHWA for flight in known icing conditions.

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[59] *Cessna Model 208B (675 SHP) Pilot Operating Handbook and FAA Approved Airplane Flight Manual Supplement S1: Known Icing Equipment*, Revision 5 (10 February 2009), p. S1-13.

1.17.1.4 *Wasaya Cessna 208B operations: 09 to 11 December 2015*

The investigation examined records from Wasaya's Cessna 208B operations during the period from 09 to 11 December 2015, during which it had 2 Caravans operating from its CYRL sub-base, and 3 Caravans from the CYPL sub-base. Of the 5 aircraft, C-FHWA, based at CYPL, was the only one certified for flight in known icing conditions.

During this period, the 3 Caravan aircraft and associated crews at the CYPL sub-base operated 31 flights within the area of operations to the north. A summary of these flights is shown in Table 8.

Table 8. Wasaya Pickle Lake (CYPL) Cessna 208B operations 09 to 11 December 2015

	09 December 2015	10 December 2015	11 December 2015
Departures from CYPL	4	4	4
Total number of flights	12	13	6
Operating period (Eastern Standard Time)	0817 to 1541	1100 to 1804	0821 to 1150
Maximum recorded altitude (feet ASL)	800 to 6500 VFR 5500 to 8500 IFR	850 to 6200 VFR 6500 to 8500 IFR	4450 to 8100
VFR/IFR	Both	Both	VFR
Comments	IFR flights conducted in C-FHWA	• IFR flights conducted in C-FHWA • C-FHWA's departure weight was 9062 pounds on the 5th leg of the day.	• C-FKAD (WSG128) returned to CYPL after encountering icing; departure weight was 9062 pounds. • C-FHWA's departure weight was 8813 pounds on the 2nd leg of the day.

Also during this period, the 2 Caravans at the CYRL sub-base operated 34 flights within the area of operations to the north. A summary of these flights is shown in Table 9.

Table 9. Wasaya Red Lake (CYRL) Cessna 208B operations 09 to 11 December 2015

	09 December 2015	10 December 2015	11 December 2015
Departures from CYRL	6	3	7
Total number of flights	11	5	18
Operating period (Eastern Standard Time)	0938 to 1521	0935 to 1146	0856 to 1852
Maximum recorded altitude (feet ASL)	1550 to 2600	1700 to 1900	1300 to 2350
VFR/IFR	VFR	VFR	VFR
Comments		One CYRL departure encountered poor weather en route and returned to CYRL from 25 nm N.	

1.17.1.5 *Wasaya Cessna 208B pilot initial technical ground training*

For initial training, Wasaya specifies a requirement of a minimum of 20 hours of Cessna 208 technical ground training.[60] The training certificate for the pilot of WSG127 recorded a training duration of 16 hours, conducted over 2 consecutive days.

The investigation examined training records for another pilot who attended the same course in July 2015 as the pilot of WSG127. That pilot's training certificate recorded the technical ground training duration as 20 hours.

The investigation also examined training records for pilots who attended the next initial course in August 2015. These 4 pilots' training certificates all recorded the technical ground training duration as 20 hours.

Following the accident, Wasaya determined that training pilots conducting the training were not aware of the 20-hour minimum and were teaching for only 16 hours because two 8-hour days were scheduled for the training.

1.17.2 *Transport Canada*

1.17.2.1 *Oversight of Wasaya*

Transport Canada Civil Aviation (TCCA) conducts oversight of air operators to verify that they comply with regulatory requirements and "that they have effective systems in place to

[60] Wasaya Airways Limited Partnership, *Training Manual*, Amendment 1 (01 December 2011), section 5.1, p. 5-1.

ensure they comply with regulatory requirements on an on-going basis."[61] The TCCA "surveillance program includes assessments, program validation inspections (PVIs) and process inspections."[62]

The program has 2 levels of surveillance:

- Assessments and PVIs are systems-level surveillance activities, in which "findings of non-compliance are at the systems level and are meant to have enterprises correct their systems in such a way that they return to compliance and maintain that state."[63]
- Process inspections are process-level surveillance activities in which TCCA makes findings of either compliance (in which case the process inspection is terminated) or non-compliance. A process inspection can lead to initiation of a systems-level surveillance activity.[64]

If TCCA determines that additional surveillance of an operator is warranted, an enhanced monitoring (EM) program can be implemented. EM has 2 goals:

> (a) That the enterprise develops and implements measures to deal with its non-compliances, ensuring compliance with regulations during and after the period of EM; and
>
> (b) That TCCA takes a comprehensive look at the enterprise's systems, through increased regulatory surveillance activities, in order to confirm the enterprise's ability to maintain compliance with applicable regulations.[65]

The scope of the investigation's examination of TCCA surveillance of Wasaya was limited to assessments, PVIs, process inspections, and EM conducted from March 2013 to 11 December 2015.

1.17.2.1.1 March 2013: Assessment

From 04 to 12 March 2013, TCCA conducted an assessment of Wasaya with a team of 11 inspectors and determined that Wasaya did not comply with a number of assessment expectations. It raised 2 major findings (regarding management review, and training and competence) and 4 moderate findings (regarding safety plan, documentation [2 findings], and quality assurance). On 17 June 2013, Wasaya submitted to TCCA a corrective action plan (CAP) describing how the company would return to compliance with the regulations.

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61 Transport Canada, Advisory Circular (AC) SUR 004: Civil Aviation Surveillance Program, (19 November 2015), subsection 3.0(1).

62 Ibid.

63 Ibid., subsection 4.1(2).

64 Ibid., subsection 4.1(3).

65 Transport Canada, Staff Instruction SI SUR-002, Enhanced Monitoring Program (02 December 2013), subsection 5.0(1).

1.17.2.1.2 October 2013: Process inspection

On 24 and 25 October 2013, TCCA conducted a process inspection of Wasaya to ensure that the Wasaya CAP for the March 2013 assessment met the regulatory requirements and was being followed in accordance with the company's documented procedures. The process inspection made 3 findings (regarding document control, safety policy, and training and competence) that Wasaya did not meet regulatory requirements. The company subsequently produced a CAP for returning to compliance and, on 31 December 2013, submitted it to TCCA.

1.17.2.1.3 January to June 2014: Enhanced monitoring

On 07 January 2014, TCCA notified Wasaya that the company had been placed on EM because the corrective actions from the March 2013 assessment were not being implemented or were not effective. The company was required to submit a gap analysis showing the current status of its CAPs for both the March 2013 assessment and the October 2013 process inspection, and to develop and implement measures to deal with non-compliances and outstanding corrective actions.

From 07 January to 30 April 2014, the TCCA EM manager attended Wasaya facilities 10 times and attended 4 of the company's SMS meetings to conduct on-site verification of the company's corrective actions.

On 09 May 2014, TCCA notified Wasaya that the March 2013 assessment was closed. The assessment findings had been addressed and corrected through the company's CAP, and the corrections had been found by TCCA to be acceptable, implemented, and completed.

1.17.2.1.4 June 2014: Program validation inspection

To verify that Wasaya had returned to compliance and had the systems in place to ensure ongoing compliance with regulatory requirements, the EM period culminated in a PVI conducted by TCCA from 23 June to 03 July 2014. On 11 August 2014, TCCA notified Wasaya that the PVI made 2 moderate findings regarding non-conformances (regarding documentation, and training and competence). On 25 September 2014, Wasaya submitted a CAP to TCCA outlining how it intended to return to compliance.

1.17.2.1.5 May 2015: Enhanced monitoring closure

On 14 May 2015, TCCA notified Wasaya that the findings generated by the June 2014 PVI had been addressed and corrected through the company's CAP; that TCCA found the corrections to be acceptable, implemented, and completed; and that the EM begun in January 2014 was closed.

1.17.2.2 *Policies and procedures for aircraft maintenance schedules*

TC provides policy and procedural guidance to its staff regarding development and approval of aircraft maintenance schedules. The procedures are intended for any aircraft, including those operated commercially.[66]

TC approval is required for amendments to maintenance schedule related to an increase in task intervals.[67] Applications for amendment must be submitted with justification for each amendment. [68] When TC staff review an application for amendment, they follow a procedure calling for the amendment to be compared with the maintenance program basis,[69] and stating that "type certificate holder's recommendations are generally preferred"[70] as the basis.

When a maintenance schedule or amendment has been approved by TC, the procedure is to return the original copy to the applicant, with copies placed in TC's files for the aircraft and operator.[71]

1.18 *Additional information*

1.18.1 *Decision support systems*

The TSB has previously investigated occurrences involving pilot self-dispatch systems and issued the following findings as to risk:

> The lack of procedures and tools to assist pilots in the decision to self-dispatch leaves them at increased risk of dispatching into conditions beyond the capability of the aircraft.[72]

> Self-dispatch systems rely on correct assessment of operational hazards by pilots…. Unless pilots are provided with adequate decision support tools, flights may be dispatched with defences that are less than adequate. [73]

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66 Transport Canada, TP 13094E, *Civil Aviation Maintenance Schedule Approval Policy and Procedures Manual* (June 2006), Chapter 1, section 3.1.2, p. 1.

67 Ibid., Chapter 5, section 5.5, p. 3.

68 Ibid., Chapter 3, section 13.3, p. 10.

69 Ibid., Chapter 3, section 11.1, p. 9.

70 Ibid., Chapter 3, section 12.1, p. 9.

71 Ibid., Chapter 3, section 14.2, p. 11.

72 TSB Aviation Investigation Report A12C0005, Finding as to risk 3.

73 TSB Aviation Investigation Report A07C0001, Finding as to risk 5.

> If a flight is planned and authorized solely by the pilot, with no cross-check for compliance with existing regulations, there is a risk that deviations will continue undetected, reducing the safety of the flight.[74]

A decision support system

> is a system under the control of one or more decision makers that assists in the activity of decision making by providing an organized set of tools intended to impart structure to portions of the decision-making situation and to improve the ultimate effectiveness of the decision outcome.[75]

These systems range from complex computer-based systems to simple paper forms.

An example of a simple risk assessment decision support form for air taxi operations is shown in Appendix N. This example was introduced by a Canadian operator in 2015, and crews are required to complete the risk assessment checklist before all departures, with the exception of training flights, pilot flight tests, and aircraft test flights. Any risk assessment score greater than 25 requires approval to proceed from both the operations manager and the chief pilot. The risk assessment checklist is retained with other dispatch-related documents.

The OFP prepared by the pilot of WSG127 did not include, and was not required to include, an explicit means of identifying potential hazards and documenting their mitigation. The company did have a crew briefing checklist available on its SMS website (Appendix O); however, its use was not required. None of the OFPs examined during the investigation included a copy of it, indicating that it was not used by Wasaya's Caravan pilots.

During its daily operations teleconference, Wasaya did not use, nor was it required to use, a decision support tool to identify and mitigate risk at a systemic level.

1.18.2 Risk posed by flight in icing conditions

In-flight ice accretion can substantially degrade aircraft performance and can also result in loss of control. Since 2000, the TSB has identified at least 23 other occurrences involving aircraft lighter than 10 000 kg flying into icing conditions, in which aircraft performance was degraded or loss of control occurred.[76] Many of these flights landed without injury to persons or damage to the aircraft. However, some occurrences resulted in multiple fatalities and aircraft destruction.

1.19 Useful or effective investigation techniques

Not applicable.

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74 TSB Aviation Investigation Report A13Q0098, Finding as to risk 10.

75 G. M. Marakas, *Decision Support Systems in the 21st Century* (Prentice-Hall, 1998).

76 TSB aviation investigation reports A00W0079, A01W0304, A04O0103, A05C0187, A05P0018, A07W0003, A08W0237, A12C0005, and A14W0181. TSB Class 5 occurrences A01C0010, A01W0127, A03P0313, A05P0018, A05C0217, A05C0225, A06O0076, A07P0045, A07W0063, A08W0220, A10O0243, A11O0234, A13C0004, and A14W0002.

2.0 Analysis

2.1 Introduction

In this occurrence, the aircraft had no known defects, and all damage was attributed to impact forces. Therefore, the analysis will discuss risk management by Wasaya and its pilots, aircraft performance in icing conditions, aircraft servicing and loading, pilot training, and crashworthiness of the emergency locator transmitter (ELT).

2.2 Wasaya risk mitigation and Cessna 208B operations

In January 2015, Wasaya conducted a risk assessment regarding certifying its Cessna 208B aircraft to operate in known or forecast icing conditions. The assessment identified several hazards, such as lack of pilot experience in such operations, operation of a fleet with mixed configurations, and exceedance of aircraft capabilities as a result of ice accumulation. The risk assessment proposed a number of mitigation strategies and an implementation plan, and concluded that the post-mitigation risk level of moderate was acceptable.

Two mitigation strategies were implemented. The first was new training requirements (the Cessna Cold Weather Operations Course), which the company provided to its Caravan pilots in fall 2015. The second was to make the Cessna 208B pilot's operating handbook (POH) Supplement S1 available to pilots. Other mitigation strategies had been proposed but had not been fully implemented.

Pilot compliance with Supplement S1 was another strategy that the risk assessment had proposed. However, the investigation determined that some Wasaya Caravan pilots did not always comply with some of the limitations specified in Supplement S1, the Cessna 208B POH, and the Supplemental Type Certificate (STC) aircraft payload extender (APE) III. Multiple flights had been carried out in forecast icing conditions with aircraft that were prohibited from operating in icing, including the 2 flights on the day of this accident. Additionally, the investigation identified 2 instances of Wasaya's only icing-certified Caravan (C-FHWA) departing into forecast icing conditions with a weight greater than 8550 pounds. Both of these issues are discussed in subsequent sections of this report. The fact that these non-compliances were found is an indicator of ineffective pilot training and supervision.

Another mitigation strategy proposed by the risk assessment was amendment of the company's Cessna 208B standard operating procedures (SOPs) before the company began flights in known or forecast icing conditions. However, as of 11 December 2015, the SOPs had not yet been amended as proposed, and the original edition remained in effect.

A further proposed mitigation strategy was to continue current maintenance practices for de-icing boot installation and upkeep. However, as discussed in Section 2.7, the company's current practices had unidentified deficiencies regarding servicing of airframe and propeller boots with ICEX II fluid.

Although the January 2015 risk assessment concluded that the post-mitigation risk level was moderate and acceptable, not all mitigation strategies had been implemented by the time of this accident in December 2015, and the company was exposed to higher risk than it had anticipated.

The unimplemented mitigation strategies were likely the result of missing or ineffective follow-up by Wasaya. On the specified follow-up date in May 2015, the company's safety management system (SMS) database did not automatically generate follow-up reminders, and it is likely that the absence of a reminder resulted in the follow-up not occurring.

In addition, from 2013 through 2015, Wasaya had experienced difficulty in implementing corrective action plans prepared in response to Transport Canada Civil Aviation (TCCA) findings of regulatory non-compliance; as a result, the company was under enhanced monitoring for a portion of this period. The fact that, in 2015, the company did not fully implement its own internal risk-mitigation plan is also indicative of an ongoing problem with follow-up action.

By December 2015, Wasaya had modified the first of its Caravans, C-FHWA, with additional equipment to certify it for flight in forecast or known icing conditions. The company was collecting information on whether the certified aircraft provided the benefits expected, and the remaining 4 aircraft were still prohibited from such operations.

Thus, Wasaya had not implemented all of the mitigation strategies from its January 2015 risk assessment of Cessna 208B operations in known or forecast icing conditions, and the company remained exposed to some unmitigated hazards that had been identified in the risk assessment.

The investigation examined meteorological information for 09 to 11 December 2015 that would have been readily available to Wasaya's staff and pilots during the morning preparation for daily operations.

During this period, the graphical area forecasts (GFAs) showed that the northwestern region of Ontario, where Wasaya operated, was expected to periodically experience freezing fog, freezing drizzle, mist, snow, reduced visibility, and low cloud ceilings. These conditions varied from day to day, and were predicted to be mainly local or patchy in spatial coverage, with other portions of the area predicted to have good visibility and cloud ceilings at 3000 feet above sea level (ASL). An exception was on 10 December, when extensive spatial coverage of ceilings from 300 to 800 feet above ground level (AGL) was forecast.

The GFAs indicated that significant icing conditions were expected in the area throughout the period. For each day, the GFAs predicted moderate mixed icing from about 3000 to 5000 feet ASL throughout the area and local spatial coverage of moderate mixed icing from the surface to about 3000 feet ASL due to freezing drizzle.

The investigation also examined Wasaya's Cessna 208B operations from 09 to 11 December 2015. During this period, the company operated 31 flights with the 3 Caravans based at Pickle Lake Airport (CYPL) and 34 flights with the 2 aircraft based in Red Lake

Airport (CYRL). The operating period each day was within the validity times of the GFAs discussed above. CYRL-based flights operated exclusively under visual flight rules (VFR), whereas CYPL-based flights were under both VFR and instrument flight rules (IFR) for aircraft C-FHWA, and VFR for the other 2 aircraft. The maximum recorded operating altitudes of VFR flights based from CYRL ranged from 1300 to 2600 feet ASL, whereas those from CYPL ranged from 800 to 8100 feet ASL. Altitudes used for IFR flights ranged from 5500 to 8500 feet ASL. Two of the 65 flights returned to their bases within about 15 minutes after departure.

The extensive Cessna 208B operations during this period when icing conditions were forecasted indicates that the associated risk was deemed acceptable to Wasaya, as its risk assessment had concluded. However, the mitigation strategies proposed had not been fully implemented, and the company was still exposed to some of the hazards it had identified through the risk assessment. The company was operating a fleet with mixed configurations: 1 aircraft was certified for flight in icing conditions; the other 4 were not. Given the forecast icing and the number of flights operating, it was likely that one or more flights would encounter icing conditions possibly exceeding aircraft capabilities. The pilot of the flight that returned to CYPL expected that there was a chance of encountering icing. It is likely that other pilots had similar expectations.

Thus, there was a company norm of dispatching Cessna 208B flights into forecast icing conditions, although 4 of Wasaya's 5 Cessna 208B aircraft were prohibited from operating in these conditions.

2.3 Flight authorization and release

To assist in controlling its day-to-day operations, Wasaya held a daily teleconference, which reviewed the planned flights for the day and other operational factors. This assisted the company in making operational decisions.

The teleconference participation and format, on 11 December 2015, was similar to that on previous days, and included a review of forecast weather conditions, which were much the same as the previous 2 days. The weather forecast was one of several operational factors discussed. The planned Caravan flying for the day was very similar to what had been flown the previous 2 days. The company did not employ any specific risk assessment tools or checklists to assess daily operations and was not required to do so. The information available to the teleconference participants likely indicated to them that operations could proceed much as they had during the previous 2 days.

Wasaya used a 2-step process to dispatch flights, in which the flights were first authorized by the company and then released by the respective pilot-in-command (PIC). Authorization was delegated to duty managers, who assessed aircraft and pilots available, passenger and cargo loads, and other factors, and then prepared the daily flying plan, which was posted to show authorized flights.

The station manager at CYPL had prepared the Caravan flying plan on the previous 2 days, and the plan for 11 December 2015 was much the same. The station manager likely did not perceive any change in risk from what had previously been acceptable.

Under the pilot self-dispatch system, it then became the responsibility of the pilot of WSG127 to release the flight. In doing so, the pilot would assess weather and airport conditions, aircraft capabilities and limitations, and aircraft load in the operational guidance framework provided by the regulations, company operations manual, and SOPs. The Wasaya Caravan SOPs were an important resource available to the pilot; however, they had not yet been updated owing to ineffective follow-up of the company's SMS risk assessment. Consequently, important information was not available regarding the procedures to be used in icing conditions by the company's Caravan pilots.

The pilot of WSG127 had flown C-FKDL repeatedly during the week before the accident and was almost certainly aware that the aircraft was prohibited from flight in forecast or known icing. This limitation was prominently placarded in the cockpit in view of the pilot.

The pilot's flight planning was done at a computer with Internet access, which was used by other pilots to check weather. Although no information was available to show what weather information the pilot reviewed, it is very likely the pilot did check the weather. It is likely the pilot would have reviewed the routine meteorological report (METAR) and the aerodrome forecast (TAF) for CYPL and Big Trout Lake Airport (CYTL), as well as the GFA for the Ontario–Quebec region, and would have been aware of the forecast for moderate mixed icing.

Other information about the icing was available. The NAV CANADA Automated Supplementary Enroute Weather Predictions (ASEP) service can depict the horizontal and vertical extent of forecast icing, but it is not known whether the pilot used the service. Additionally, the U.S. Current Icing Product (CIP) predicted a 60% probability of light icing in the CYPL area. However, given that this is a U.S. product, it is likely the pilot did not use it.

The pilot's weather review was made in the context of a company operating norm, which accepted the risk of the icing forecast by the GFA. The pilot had flown the previous 2 days with such a forecast, as had his peers, and the forecast conditions on 11 December 2015 were very similar. It is likely the pilot assessed the risk posed by the weather forecast as acceptable.

The pilot also needed to assess the load to satisfy the company requirement to calculate weight and balance for the flight. However, parts of the load spanned several zones, and there was no load distribution form available. As discussed below, in Section 2.9, it would have been difficult for the pilot to estimate the load distribution and calculate the centre of gravity. Although the investigation determined that the centre of gravity was within limits, the pilot likely did not know this with any certainty. The pilot likely estimated that the centre of gravity was acceptable based on his previous experience.

The weight of WSG127 could be calculated using the cargo manifests, and the investigation determined the take-off weight was 9009 pounds. It is likely the pilot was aware that the weight was below the maximum take-off weight for the APE III modification.

Had C-FKDL been certified for flight in forecast icing, the maximum weight for WSG127 would have been 8550 pounds. This reduced weight would have reduced the lift required, angle of attack, and stall speed. By operating at a higher weight, WSG127 needed to produce more lift at a higher angle of attack, and it had an increased stall speed. The high take-off weight of WSG127 increased the severity of degraded performance when the flight encountered icing conditions.

The pilot of WSG127 signed the operational flight plan and released the flight. The pilot's signature on the flight dispatch clearance (FDC) form indicated the pilot was satisfied that the flight could be safely completed as planned and that the aircraft weight and centre of gravity were within limits. The pilot's acceptance of the increased risk posed by the weight and weather conditions was likely a result of ineffective training and the company norm of accepting such operations.

Although the aircraft was prohibited from flying in known or forecast icing conditions, WSG127 was dispatched into forecast icing conditions.

The PIC is the final defence in a pilot self-dispatch system and is expected to comply with all rules, procedures, and limitations. In this instance, the pilot released and flew an aircraft that was prohibited from doing so into forecast icing conditions, with catastrophic consequences. This accident occurred in the context of a company norm of authorizing such flights and Caravan pilots routinely being dispatched into forecast icing conditions.

The Type C pilot self-dispatch procedures and practices in use at Wasaya at the time of the occurrence did not ensure that operational risk was managed to an acceptable level. As shown in this occurrence, without effective risk-management processes, aircraft may continue to be dispatched into forecast or known icing conditions that exceed the operating capabilities of the aircraft, increasing the risk of degraded aircraft performance or loss of control.

2.4 Decision support tools

Pilot self-dispatch systems are commonly used by air operators across Canada, and Wasaya used one for all of its flights, including WSG127. This system places responsibility on the PIC for decision making about all aspects of the flight, including hazard identification and risk management.

Wasaya provided extensive operational guidance in the COM and SOPs regarding the decisions for which pilots were responsible. However, a pilot self-dispatch system relies entirely on pilots' knowledge of and compliance with regulatory and company requirements.

Decision support systems were widely used within Wasaya. The daily flying plans for each base were used by managers to adapt to changing situations. The daily operations teleconference was used to make operational decisions. Some decision tools available to pilots included spreadsheets or slide rules to calculate the centre of gravity, the load control form (weight-and-balance form), and the FDC form. However, in CYPL, the load distribution form was not available to Caravan pilots because it was not being used by loading crews.

Additionally, the company did not employ any formal risk-management decision support tools (i.e., forms, checklists, etc.) to assist flight operations managers and pilots in identifying and mitigating hazards, nor was it required to do so. Although the company did have a crew briefing checklist available on its SMS website, there was no requirement to use it. The investigation determined that Wasaya's Caravan pilots did not use this form, which indicates that its existence was not well known. Even if the form were used, it was better suited to assisting pilots in ensuring pre-flight duties were completed than to identifying hazards or mitigations.

The availability of adequate risk-management decision support tools may not have made a difference in the flight of WSG127. However, such tools could improve pilot self-dispatch risk management in a broad range of situations faced daily by pilots across Canada.

The absence of a formal risk assessment during operational control processes, such as flight authorization, daily operations teleconferences, or flight dispatch release, increases the likelihood of a flight being authorized or released with risks that are either unidentified or not adequately assessed and mitigated.

Pilot self-dispatch systems rely on pilots correctly assessing operational hazards. If pilots operating under self-dispatch do not have adequate tools to complete an operational risk assessment before releasing a flight, there is an increased likelihood that hazards will not be identified or adequately mitigated.

2.5 Icing and aircraft performance

Ice accumulation on airframes and propellers is known to degrade aircraft performance. With the Cessna 208B, this hazard is addressed by the manufacturer's and Wasaya's operating procedures, which specify that it is necessary to take immediate action to exit icing conditions when they are encountered.

In the case of WSG127, the flight took off at a weight of 9009 pounds. At that weight, the aircraft performance charts indicate that the aircraft should have been capable of climbing at about 800 feet per minute (fpm) at 105 knots indicated airspeed (KIAS).[77]

The initial climb rate at the beginning of the recorded data was about 800 fpm, as expected, but the airspeed decreased to as low as 98 knots calibrated airspeed (KCAS) before the flight descended, and accelerated to 120 KCAS before the flight began to climb again at 110 KCAS and 600 fpm. This degraded performance indicates WSG127 was experiencing increased

[77] This analysis uses both knots indicated airspeed (KIAS) and knots calibrated airspeed (KCAS). For the Cessna 208B, these speeds are equal through the range of 100 to 175 knots at 8750 pounds and power set for level flight.

drag as early as 0903. It is likely that the flight was operating in icing conditions by this point.

When a Cessna 208B aircraft with a cargo pod installed is operating in icing conditions, the maximum aircraft weight is reduced to 8550 pounds and the minimum speed in icing is 120 KIAS, which is the climb speed recommended by Wasaya. Even if C-FKDL had been equipped and certified for flight in icing conditions, it was being operated at a higher weight and a lower climb speed than was prescribed.

Lacking the full suite of ice-protection systems, C-FKDL was more vulnerable to icing encounters than a Cessna 208B certified for flight in icing conditions. Given the aircraft weight at the time of the occurrence, the aircraft would have been operating at a higher angle of attack, which could produce ice accretion on the underside of the wing aft of the leading-edge de-icing boots. This ice accretion would have caused a further deterioration in aircraft performance.

The analysis of the CYPL radiosonde observation at 0700 indicated a high probability of moderate to severe clear icing at the altitudes through which WSG127 was climbing, and local areas of freezing drizzle were forecast. As stated in the Cessna 208B POH, flight in freezing drizzle can result in ice that cannot be shed by the ice-protection systems, seriously degrading performance. While it cannot be known with certainty, there was a high probability that WSG127 encountered freezing drizzle during the climb.

As the climb continued, the rate of climb decreased to about 400 fpm, then decreased further to about 250 fpm near the top of climb. As well, the estimated airspeed decreased from 110 KCAS to as low as 98 KCAS.

The aircraft performance exhibited by WSG127 was significantly less than the expected performance and degraded progressively, consistent with greater-than-normal airframe drag and decreased propeller thrust. Such degraded performance is consistent with an accumulation of ice on the airframe and propeller, and it is likely that the drag was increasing as the aircraft accumulated more ice during the climb.

The charted stall speed of C-FKDL at a weight of 9062 pounds with flaps up, wings level, and idle power is 78 KCAS. The engine and propeller were likely set to the company's recommended climb power, and no information was available regarding the stall speed with power above idle. Given that the Cessna 208B stall speed may increase by up to 20 knots because of ice accumulation, the power-off stall speed of C-FKDL could have been as high as 98 KCAS.

After reaching the top of the climb, the aircraft began slowly descending just before Event 1 (Appendix K). It could not be determined whether Event 1 began during wings-level flight or at the beginning of a turn initiated by the pilot.

A turning manoeuvre would have increased the lift demand on one of the wings and effectively increased the stall speed on that wing. With the low estimated airspeed at the time, and with the combination of increased stall speed and high drag from accumulation of ice, the available margin above stall speed would have been significantly reduced.

The sudden flight-path departure at Event 1 is consistent with an aircraft encountering stall conditions at an airspeed higher than expected as a result of ice contamination of the airframe. The stall and the subsequent abrupt departure may have been aggravated by an ice-induced asymmetry between the left and right wings. The rapid attitude and track change of the aircraft, as well as the progressively steepening descent, indicate that Event 1 was likely an aerodynamic stall and the early portion of a spin.

Following Event 1, the aircraft descended at up to 7000 fpm, with the estimated airspeed rapidly increasing to about 140 KCAS. The aircraft subsequently began to climb again, indicating that the pilot had temporarily regained control of the aircraft and was recovering from the stall.

However, during the recovery, the estimated airspeed rapidly decreased, and there were acceleration forces as the pilot pitched the aircraft up to arrest the descent. This rapid loss of airspeed is consistent with the high drag of an aircraft significantly encumbered by ice.

The low estimated airspeed, rapid attitude change of the aircraft, and progressively steepening descent during Event 2 (Appendix K) indicate that there was likely a second aerodynamic stall, which occurred at an altitude at which recovery was not possible. The small track change during Event 2 indicates that a spin likely did not occur at that point.

The aircraft performance exhibited by WSG127 is consistent with operation in icing conditions that exceeded the capabilities of the aircraft, leading to a departure from controlled flight that was not recoverable under the circumstances. WSG127 experienced substantially degraded aircraft performance as a result of ice accumulation, resulting in aerodynamic stall, loss of control, and collision with terrain.

In the case of WSG128, which returned to CYPL after encountering icing, the take-off weight was 9062 pounds. This aircraft was also prohibited from flight in known or forecast icing conditions because it was not equipped with all of the ice-protection systems needed for this aircraft type. The flight encountered icing during the climb, with an airspeed decrease of 5 to 10 knots as a result of ice accumulation. No controllability problems were experienced, although performance was degraded and visibility was obscured by ice on the windshield.

If aircraft that are not certified for flight in known or forecast icing conditions are dispatched into, and encounter, such conditions, there is an increased risk of degraded performance or loss of control.

On 11 December 2015, a third Wasaya Caravan, C-FHWA, which was certified for flight in icing conditions, departed into forecast icing conditions on the second leg of the day with a weight of 8813 pounds. The previous day, when icing conditions were also forecasted, C-FHWA had departed on a flight with a weight of 9062 pounds.

If aircraft that are certified for flight in known or forecast icing conditions are dispatched into, and encounter, such conditions, at weights exceeding limitations, there is an increased risk of loss of control.

2.6 In-flight pilot decision making

As discussed in Section 2.5, WSG127 was likely operating in icing conditions as early as 0903, and the aircraft continued accumulating ice, whether intermittently or continuously, until Event 1 at about 0909. Similarly, WSG128, which returned to CYPL, was operating in icing conditions for about 5–6 minutes. The pilot of WSG128 used the de-icing and anti-icing systems that were installed.

The residual ice on C-FKDL following the crash indicates that the pilot of WSG127 used the leading-edge boots at least once at some point during the flight; however, impact-related damage prevented the investigation from determining which other systems were used. It is very likely the pilot would have had the propeller anti-icing on.

The fact that both flights continued in icing for at least 5 minutes is a substantial deviation from the guidance provided by the Wasaya SOP, which stated that "icing conditions should be vacated immediately." Given that these 2 pilots continued in icing for so long, it is likely that the company norm of Caravan pilots self-dispatching into forecast icing also included operating in icing when it was encountered rather than immediately vacating it, as required by the SOPs. The pilot of WSG127 continued the flight in icing conditions for about 6 minutes, resulting in progressively degraded performance.

That the pilot of WSG128 also did so indicates ineffective training and the existence of a company norm to accept continued operations in icing conditions. If flights are continued in known icing conditions in aircraft that are not certified to do so, there is an increased risk of degraded aircraft performance and loss of control.

2.7 ICEX II application interval

ICEX II can be used to retard ice adhesion on the treated surface and to increase shedding of ice that has accumulated. The investigation found 2 instances in which Wasaya's approved maintenance schedule addendum for the Cessna 208B did not follow the aircraft manufacturer's recommended servicing with ICEX II. Deviations from the manufacturer's recommendations are permitted if justification is submitted to and approved by Transport Canada (TC).

In the first instance, Cessna recommended regular application of the fluid to the propeller anti-icing boots at a maximum interval of 15 flight hours; however, this interval was missing from the Wasaya maintenance schedule addendum. The company's Caravan propeller boots were not being serviced with ICEX II.

Given that ICEX II helps retard ice adhesion and increases ice shedding from boots, it follows that the absence of this application on propeller boots could lead to increased severity of ice accumulation, resulting in degraded thrust from a propeller. It is therefore likely that flight

WSG127 experienced degraded propeller performance in icing conditions because the propeller blades had not been serviced with ICEX II.

In the second instance, Wasaya specified in its approved maintenance schedule that it would apply ICEX II to Cessna 208B leading-edge boots at 100-hour intervals during the icing season. This servicing requirement applied to all of the company's Caravans, whether certified for or prohibited from flight in known or forecast icing conditions.

However, this servicing interval differed from the Cessna maintenance manual's servicing recommendation of a maximum interval of 50 flight hours. Wasaya had increased the interval to 100 hours in 2006. Although TC approved the interval increase, no records were available at Wasaya or TC to determine the justification for the increase.

Given that the leading-edge de-icing boots on C-FKDL had been serviced with ICEX II 10.6 flight hours earlier, and the aircraft was operating within the manufacturer's maximum interval of 50 hours, the increased ICEX II application interval did not play a role in the accident.

However, the greater interval between applications results in aircraft operating beyond the 50-hour interval recommended by the manufacturer. Application intervals greater than those required by the manufacturer reduce the capability of the leading-edge de-icing boots to shed ice, resulting in increased residual ice following boot operation and degraded aircraft performance.

Wasaya's approved maintenance schedule addendum for the Cessna 208B did not follow the aircraft manufacturer's recommended servicing with ICEX II fluid. As a result, the company was exposed to increased risk associated with accretion of ice on the leading-edge de-icing and propeller blade anti-icing boots of its Cessna 208B fleet.

If operators exceed aircraft manufacturers' recommended ICEX II servicing intervals, there is an increased risk of degraded aircraft performance or loss of control resulting from greater accretion of ice on the leading-edge de-icing and propeller blade anti-icing boots.

2.8 Wasaya initial technical ground training

Wasaya's company training manual requires 20 hours of technical ground training as part of pilots' initial training on the Caravan. However, the company allocated only 2 days to conduct the training, making it unlikely that the full 20 hours of required training could be delivered.

The training record showed that the WSG127 pilot had received only 16 hours of training, whereas records for other pilots taking the same course showed that they had received 20 hours. It is likely that the 16-hour duration recorded is a realistic account of the extent of training provided to the WSG127 pilot. It is also likely that other pilots on the course received less than the required 20 hours. If pilots do not receive the minimum required training, there is an increased risk that they will lack the necessary technical knowledge to operate aircraft safely.

2.9 Cessna 208B loading documentation at CYPL

Wasaya loading crew practices at CYPL did not include completion of the load distribution form for Caravan flights, although completing the form was required by company policy. Caravan pilots could calculate the aircraft weight using the freight manifests. However, because they had no information about the load distribution, they would have been unable to accurately calculate the centre of gravity for a flight. It is likely that multiple Caravan flights departed from CYPL without an accurate determination of the centre of gravity.

No load distribution form for WSG127 was found at the crash site or at the company's operations room. Calculations made after the accident showed that WSG127 was loaded within the specified take-off weight and centre of gravity limitations; therefore, the absence of a centre-of-gravity calculation did not contribute to the accident.

Given the absence of the load distribution form and the fact that the cargo loaded on WSG127 spanned several cargo zones, it would have been difficult for the pilot to estimate the load distribution and calculate the centre of gravity. If pilots are not provided with the information they need to calculate the aircraft's centre of gravity accurately, they risk departing with their aircraft's centre of gravity outside the limits, which can lead to loss of control.

2.10 Emergency locator transmitters and satellite flight-following

The ELT on board WSG127 was likely serviceable at the time of the occurrence; however, no usable signal was detected on either 121.5 MHz or 406 MHz frequencies as a result of impact-related damage to the antenna and antenna cable connections. Consequently, search-and-rescue (SAR) personnel did not have a precise location for the crash site or a signal that could be homed using onboard equipment. Therefore, the search for the crash site needed to start from the aircraft's last known position.

The TSB has investigated many other occurrences in which no ELT signal was transmitted because of issues related to the crashworthiness of the ELT antenna system. Other studies have shown that a large proportion of all ELT failures result from impact-related damage. The frequent occurrence of ELT failure indicates that existing design and certification standards do not provide an acceptable degree of crash survivability.

It is highly likely that aircraft equipped with ELT systems that meet the current design standards will continue to be involved in occurrences in which potentially life-saving SAR services are delayed as a result of damage to the aircrafts' ELT systems, reducing survivability in the event of an accident. International stakeholders' response to TSB recommendations about this safety deficiency indicates satisfactory intent. However, the deficiency will continue to exist until design standards are improved and a new generation of ELTs enters service.

If ELT antennas and cable connections are not robust enough to survive impact forces, potentially life-saving SAR operations may be impaired by the absence of a usable signal.

In this occurrence, the aircraft was equipped with a satellite tracking system, as were the company's other aircraft. Wasaya's use of a satellite aircraft flight-following system provided early warning of WSG127's abnormal status and an accurate last known position for SAR operations.

3.0 Findings

3.1 Findings as to causes and contributing factors

1. Although the aircraft was prohibited from flying in known or forecast icing conditions, Wasaya Airways Limited Partnership (Wasaya) flight 127 (WSG127) was dispatched into forecast icing conditions.

2. The high take-off weight of WSG127 increased the severity of degraded performance when the flight encountered icing conditions.

3. The pilot of WSG127 continued the flight in icing conditions for about 6 minutes, resulting in progressively degraded performance.

4. WSG127 experienced substantially degraded aircraft performance as a result of ice accumulation, resulting in aerodynamic stall, loss of control, and collision with terrain.

5. The Type C pilot self-dispatch procedures and practices in use at Wasaya at the time of the occurrence did not ensure that operational risk was managed to an acceptable level.

6. Wasaya had not implemented all of the mitigation strategies from its January 2015 risk assessment of Cessna 208B operations in known or forecast icing conditions, and the company remained exposed to some unmitigated hazards that had been identified in the risk assessment.

7. There was a company norm of dispatching Cessna 208B flights into forecast icing conditions, although 4 of Wasaya's 5 Cessna 208B aircraft were prohibited from operating in these conditions.

3.2 Findings as to risk

1. Without effective risk-management processes, aircraft may continue to be dispatched into forecast or known icing conditions that exceed the operating capabilities of the aircraft, increasing the risk of degraded aircraft performance or loss of control.

2. If pilots operating under self-dispatch do not have adequate tools to complete an operational risk assessment before releasing a flight, there is an increased likelihood that hazards will not be identified or adequately mitigated.

3. If aircraft that are not certified for flight in known or forecast icing conditions are dispatched into, and encounter, such conditions, there is an increased risk of degraded performance or loss of control.

4. If aircraft that are certified for flight in known or forecast icing conditions are dispatched into, and encounter, such conditions, at weights exceeding limitations, there is an increased risk of loss of control.

5. If flights are continued in known icing conditions in aircraft that are not certified to do so, there is an increased risk of degraded aircraft performance and loss of control.

6. If operators exceed aircraft manufacturers' recommended ICEX II servicing intervals, there is an increased risk of degraded aircraft performance or loss of control resulting from greater accretion of ice on the leading-edge de-icing and propeller blade anti-icing boots.

7. If pilots do not receive the minimum required training, there is an increased risk that they will lack the necessary technical knowledge to operate aircraft safely.

8. If pilots are not provided with the information they need to calculate the aircraft's centre of gravity accurately, they risk departing with their aircraft's centre of gravity outside the limits, which can lead to loss of control.

9. If emergency locator transmitter antennas and cable connections are not robust enough to survive impact forces, potentially life-saving search-and-rescue operations may be impaired by the absence of a usable signal.

3.3 Other findings

1. Wasaya's use of a satellite aircraft flight-following system provided early warning of WSG127's abnormal status and an accurate last known position for search-and-rescue operations.

2. The investigation could not determine whether the autopilot had been used by the pilot of WSG127 at any time during the flight.

4.0 Safety action

4.1 Safety action taken

4.1.1 Wasaya

Following this accident, Wasaya Airways Limited Partnership (Wasaya) initiated 2 safety management system (SMS) investigations. The first was triggered by the loss of flight 127 (WSG127), and the second by the return of the other Caravan flight to Pickle Lake Airport (CYPL). The actions resulting from the 2 company SMS investigations are discussed below.

4.1.1.1 Single-pilot operations

Wasaya discontinued single-pilot operations on the Cessna 208B immediately after the accident. Following a review of operations, the company provided clarification of its single-pilot procedures to all Caravan pilots. On 11 January 2016, the company resumed single-pilot operations with modifications to weather limitations for dispatch.

4.1.1.2 Minimum weather requirements for day visual flight rules flights

On 11 January 2016, Wasaya increased the minimum weather requirements for all visual flight rules (VFR) flights conducted under Operations Specification 004, from a ceiling of 300 feet above ground level (AGL) and visibility of 1 statute mile (sm),[78] on a sliding scale (Table 10).

Table 10. Increased minimum weather requirements for VFR flight dispatch

Ceiling height (feet AGL)	Minimum visibility (sm)
300	3
400	2
500	1½
600	1

4.1.1.3 Operational flight plan

On 14 February 2016, the company revised its Cessna 208B weight-and-balance ("load control") form to include a space to record the calculated centre of gravity.

On the same date, an additional step was incorporated into the approval process for the operational flight plan (OFP), in which the OFP and its component documents were checked for completeness by station operations coordinators or the systems operations control

78 Wasaya Airways Limited Partnership, *Company Operations Manual*, Revision 2 (19 December 2014), section 3.4.2.

centre (SOCC) flight follower before a flight was dispatched. This step was subsequently revised as follows: when the flight dispatch clearance (FDC) form is completed, it is sent to the SOCC before departure. The FDC is checked for content and for the captain's signature and is kept by the SOCC for the duration of the flight.

4.1.1.4 *Use of Cessna 208B load distribution form*

Following the accident, the company identified that loading crews at CYPL were not providing Cessna 208B pilots with a completed load distribution form. Wasaya reintroduced use of the form in the spring of 2016; however, company follow-up on 16 December 2016 determined that loading crews in CYPL were again not using the load distribution forms for Cessna 208B flights.

On 07 March 2017, the Wasaya director of operations (DO) issued a message to address staff confusion regarding when a load distribution form was required to be completed for Caravan flights. The message stated that loadmasters were required to produce the form for any load on a Caravan for which the captain did not supervise the loading, adding that this applied to all Caravan departures from CYPL and Red Lake Airport (CYRL).

In April 2017, CYPL flight, ground, and operations staff were briefed regarding compliance with this requirement. Follow-up audits by the DO verified that the form was being used for flights for which the pilot did not supervise loading.

4.1.1.5 *Pilot training*

The company increased the time allocated for initial Cessna 208B ground technical training from 2 days to 3 days.

4.1.1.6 *Tracking of inadvertent Cessna 208B icing encounters*

The company SMS investigation determined that more information was needed, and proposed developing a means for Cessna 208B pilots to report inadvertent icing encounters. As of 25 April 2017, the SMS had received 2 reports of inadvertent ice encounters: one in which the flight returned to the point of departure, and one in which the flight avoided further icing and continued to destination.

4.1.1.7 *Application of ICEX II*

Wasaya revised its maintenance schedule addendum for the Cessna 208B to incorporate application of ICEX II to propeller anti-icing boots at a maximum interval of 15 hours, and to reduce the maximum interval for application of ICEX II to leading-edge de-icing boots to 50 hours.

4.1.2 *Transport Canada*

Transport Canada Civil Aviation (TCCA) conducted a process inspection of Wasaya from 22 December 2015 to 04 January 2016. TCCA advised the company that the process inspection had determined that the company's Cessna 208 dispatch process was compliant.

However, TCCA determined that Wasaya's ground icing operations program was not effective and did not meet regulatory requirements. On 04 March 2016, Wasaya submitted to TCCA a corrective action plan describing how the company would return to compliance with the regulations. TCCA's follow-up was completed on 23 December 2016. The Wasaya corrective action plan was accepted, and the process inspection was closed.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 02 August 2017. It was first released on 28 September 2017.

Correction

The fourth paragraph of Section 1.15.2, *Emergency locator transmitter* has been changed to clarify that impact-related damage is responsible for the majority of non-activations. As part of this change, a new reference (Australian Transport Safety Bureau, Aviation Research Investigation AR-2012-128, A review of the effectiveness of emergency locator transmitters in aviation accidents (21 May 2013)) has been added as footnote 42, which has changed the numbering of the subsequent footnotes.

The original version of the report had stated, "A more recent study, conducted by the Canadian Mission Control Centre for SARSAT, determined that ELTs did not activate in 38% of Canadian aircraft accidents in which the aircraft sustained substantial damage."

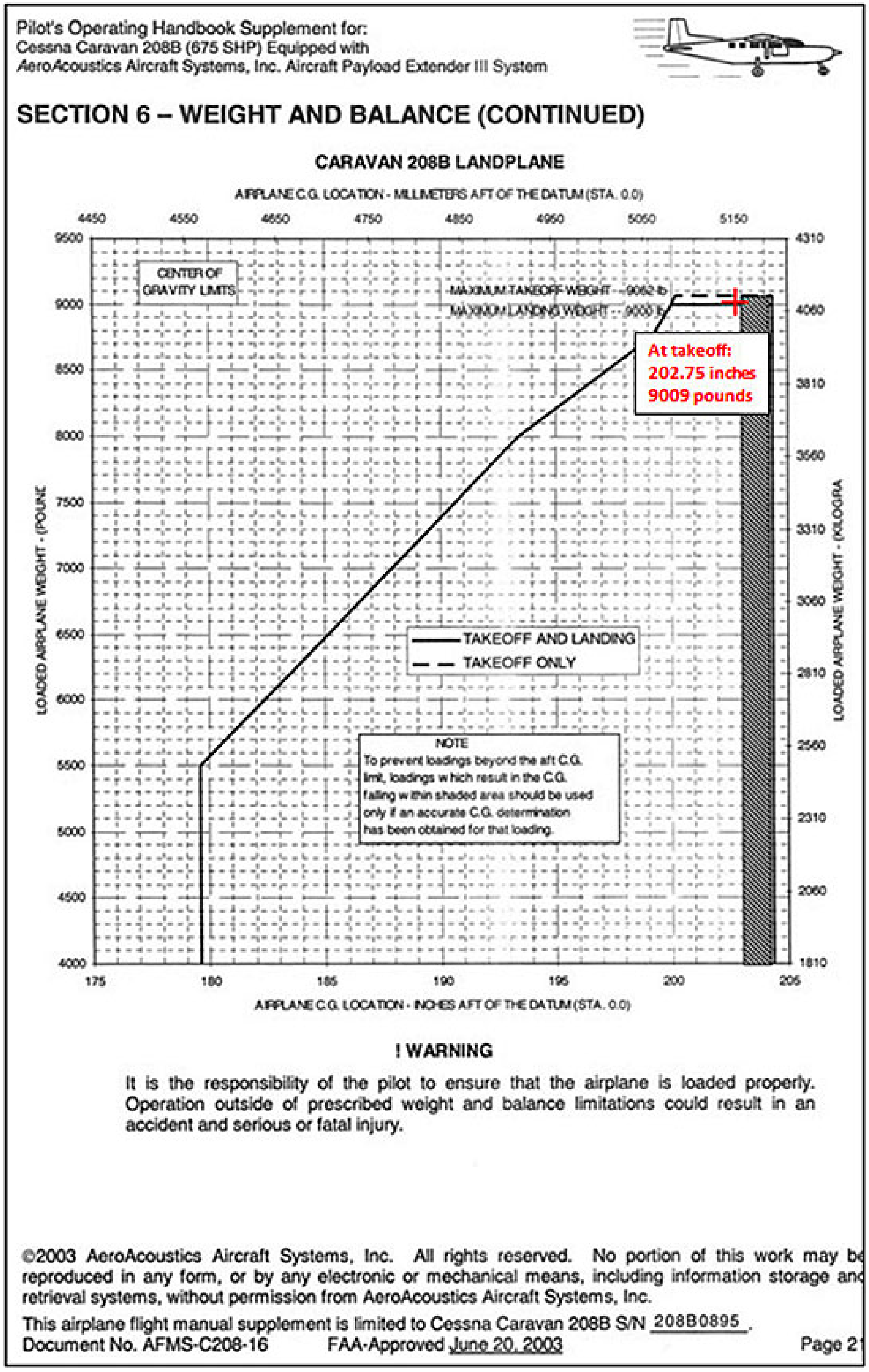
It now reads, "More recent studies, conducted by the Canadian Mission Control Centre and the Australian Transport Safety Bureau (ATSB) have found that impact-related damage (i.e., fire damage, impact damage, broken/disconnected antenna, and water damage) is responsible for the majority of non-activations."

This correction was approved by the Board on 03 October 2018; the corrected version of the report was released on 22 October 2018.

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.

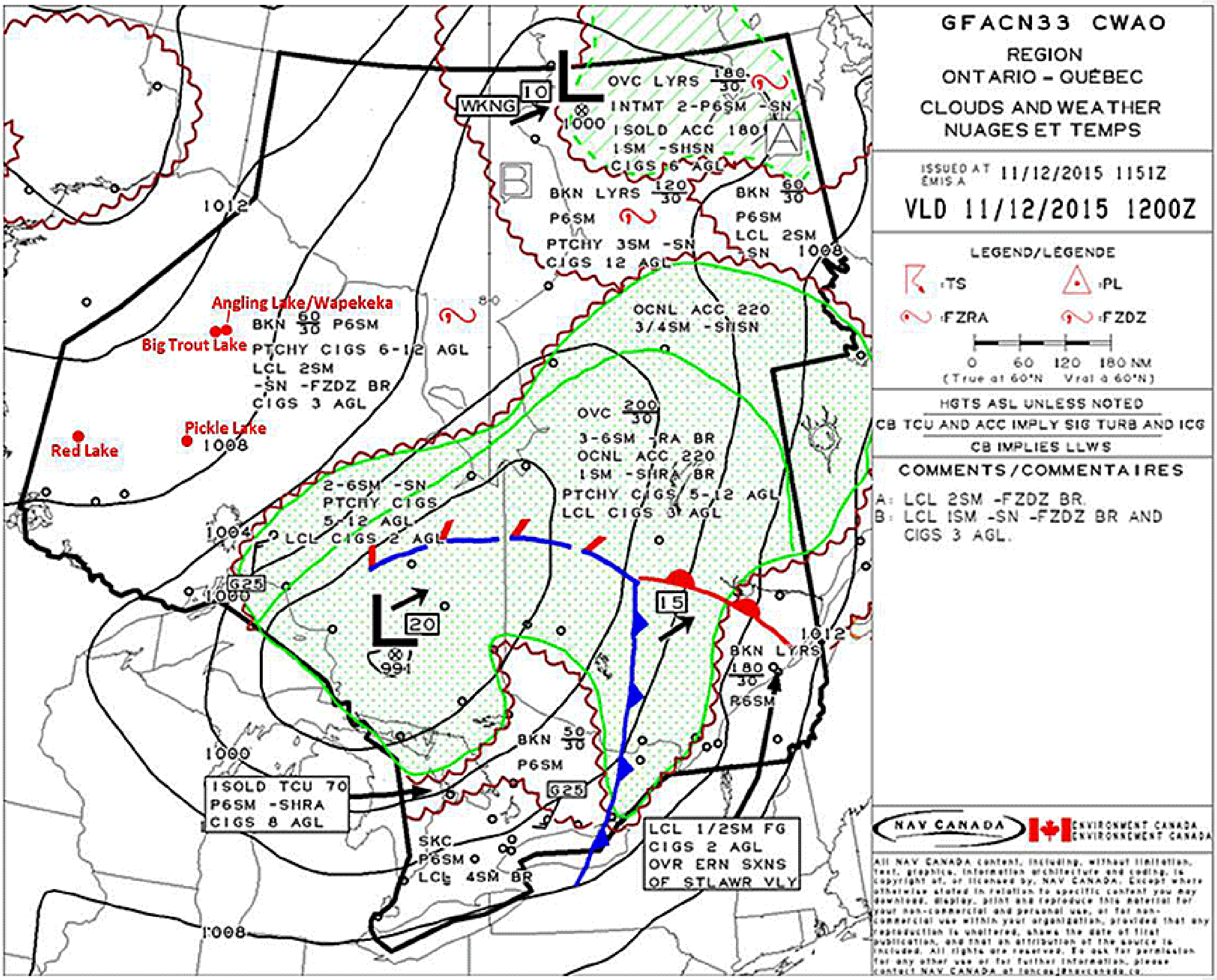
Appendices

Appendix A – Weight and balance for flight WSG127

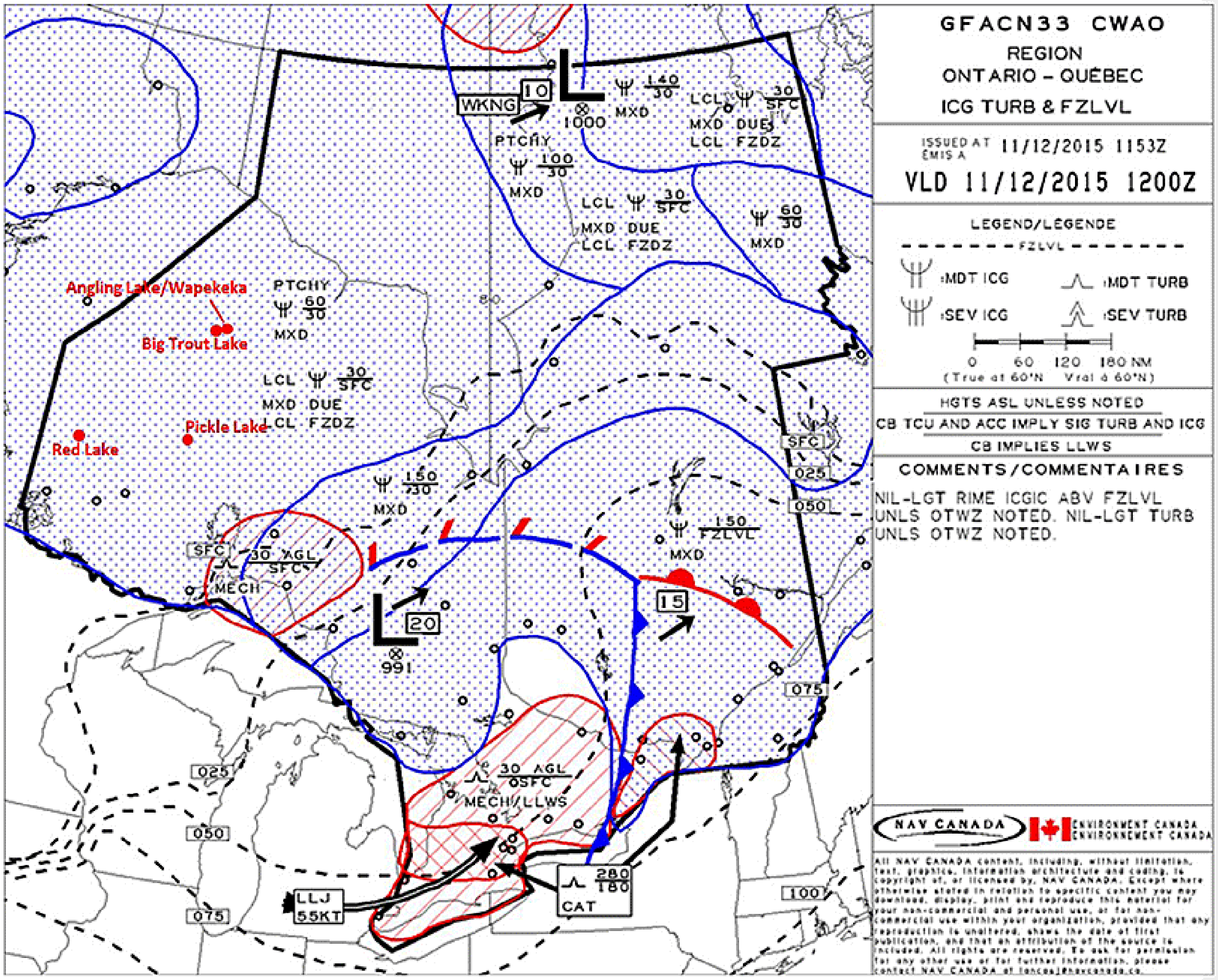


Source: AeroAcoustic Aircraft Systems, Inc., *Pilot's Operating Handbook* (POH), Supplement for Cessna Caravan 208B, Document AFMS-C208-16 (20 June 2013), section 6: Weight and Balance, p. 21. With TSB annotations.

Appendix B – Graphical area forecast CN33 valid at 0700 EST (1200 UTC) 11 December 2015



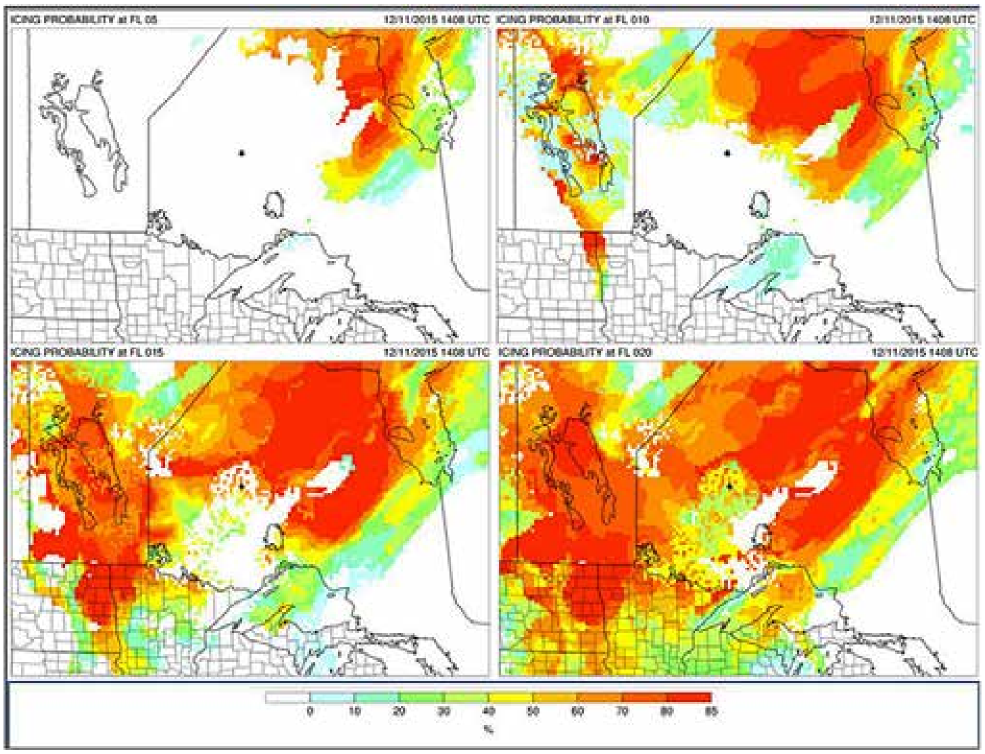
Source: NAV CANADA and Environment Canada.



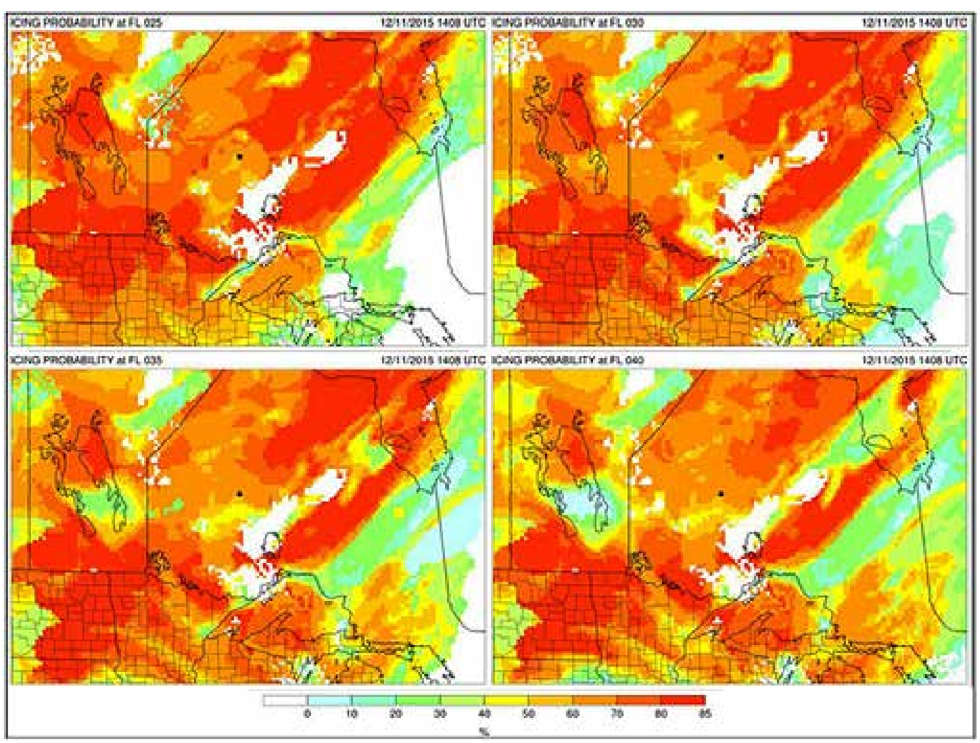
Source: NAV CANADA and Environment Canada.

Appendix C – Current Icing Product showing probability of icing: 11 December 2015 at 0908 (1408 UTC)

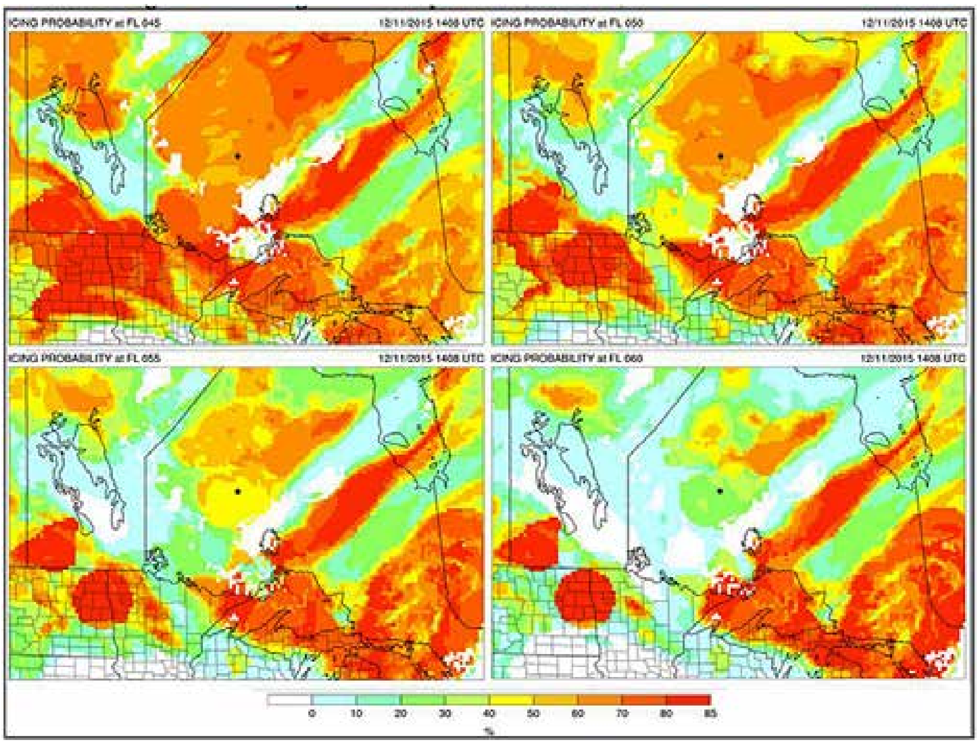
Note: The black dots represent CYPL.



Source: U.S. National Center forAtmospheric Research.



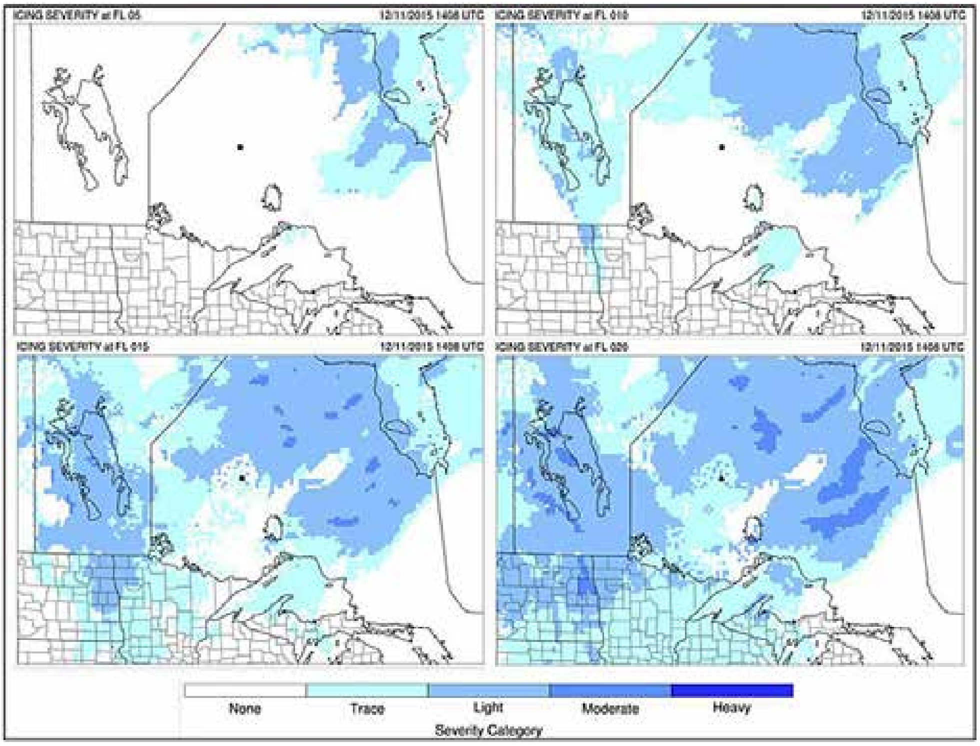
Source: U.S. National Center for Atmospheric Research.



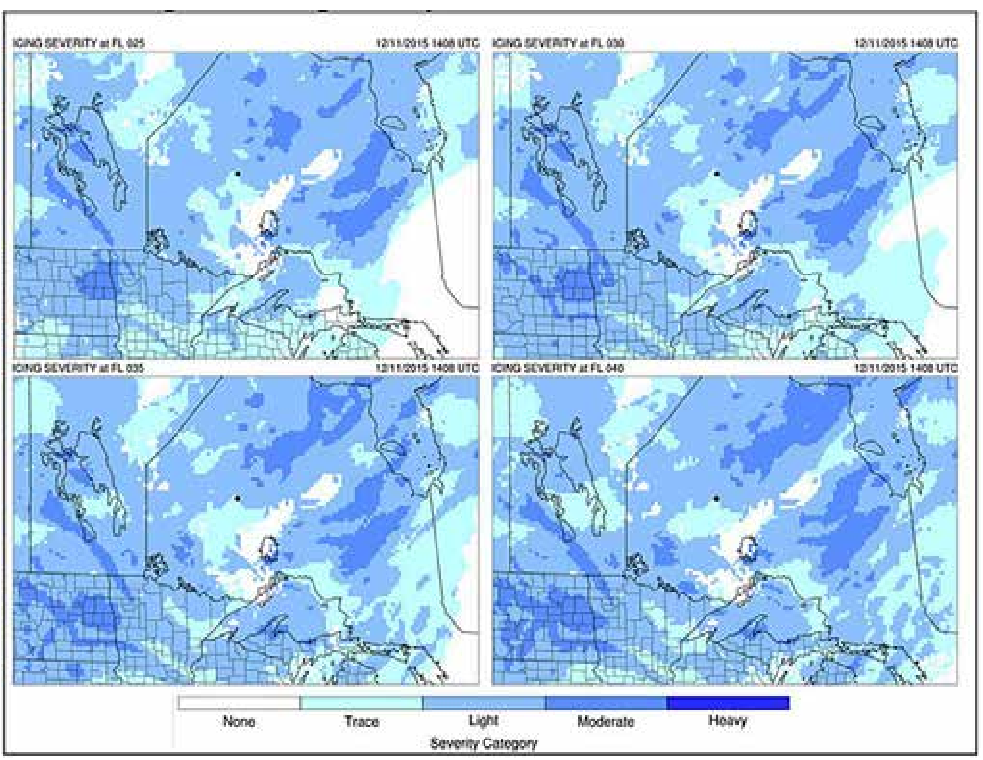
Source: U.S. National Center for Atmospheric Research.

Appendix D – Current Icing Product showing severity of icing: 11 December 2015 at 0908 (1408 UTC)

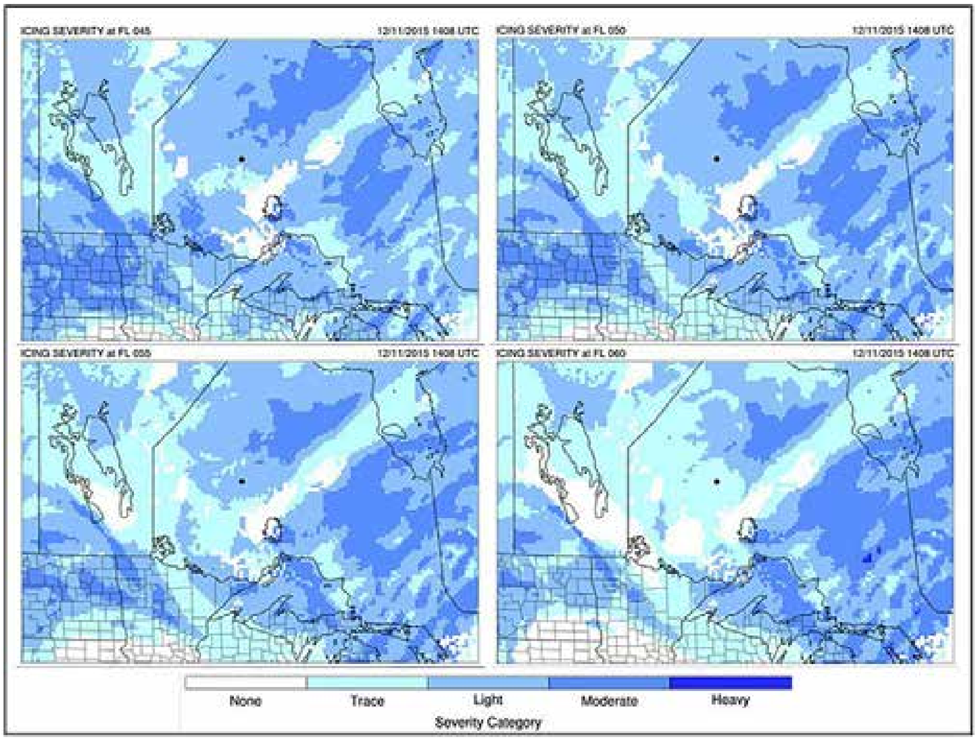
Note: The black dots represent CYPL.



Source: U.S. National Center for Atmospheric Research.

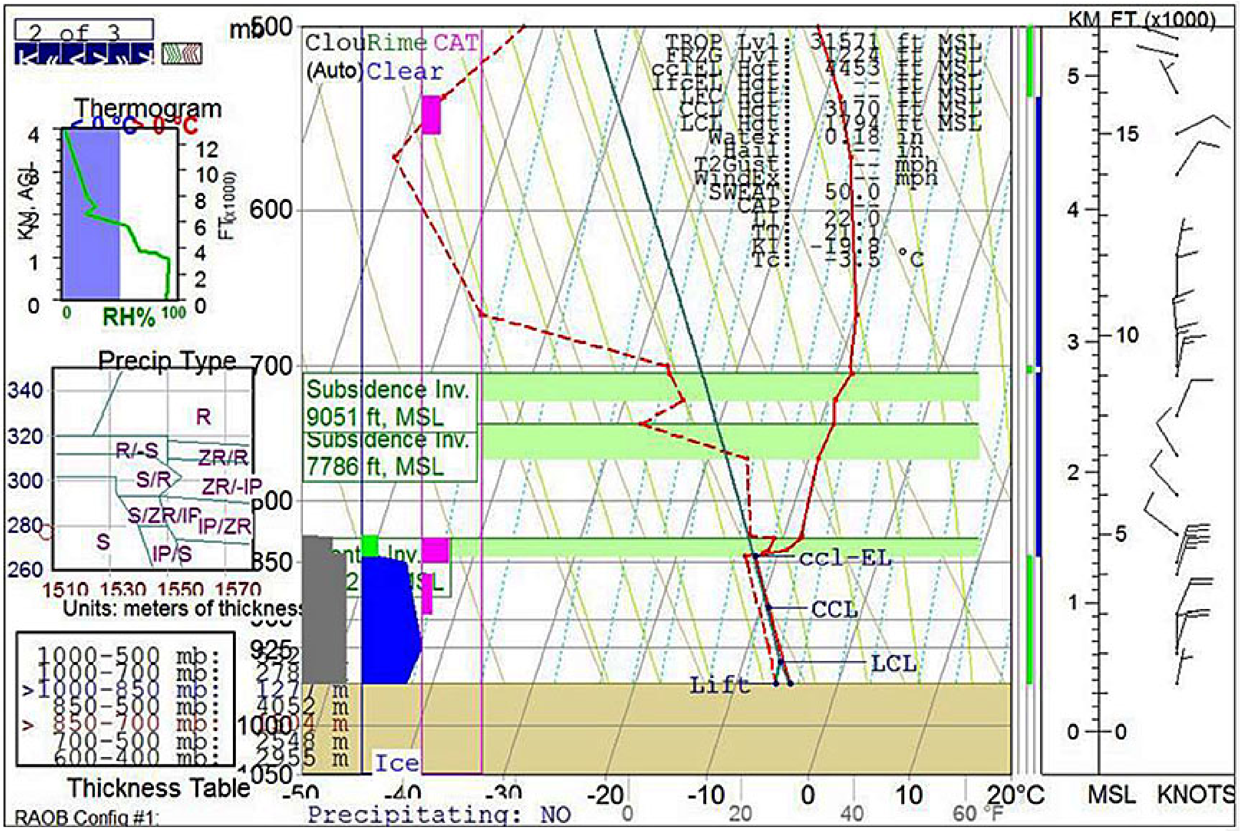


Source: U.S. National Center for Atmospheric Research.



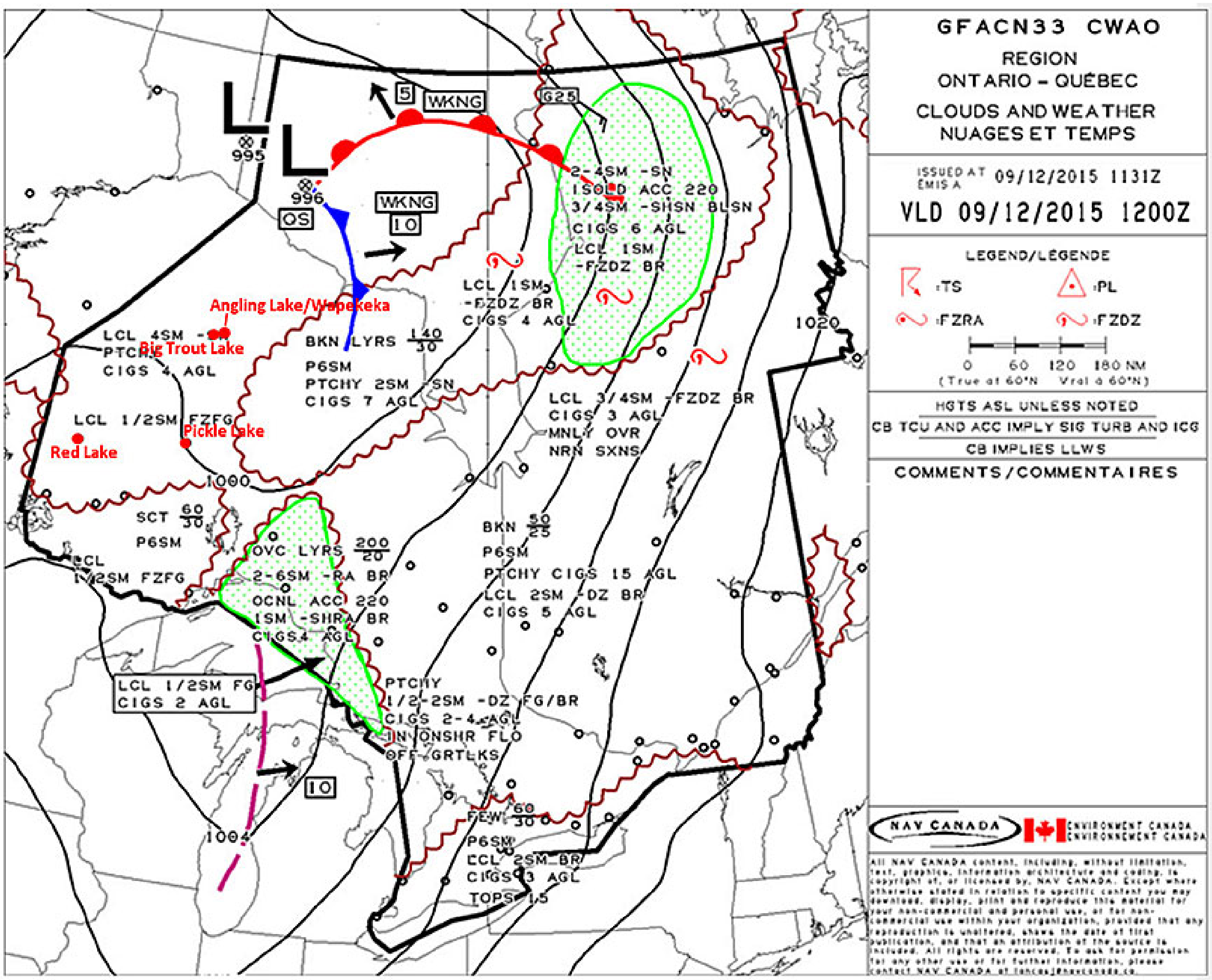
Source: U.S. National Center for Atmospheric Research.

Appendix E – Pickle Lake Airport (CYPL) radiosonde observation: 11 December 2015 at 0700 (1200 UTC)

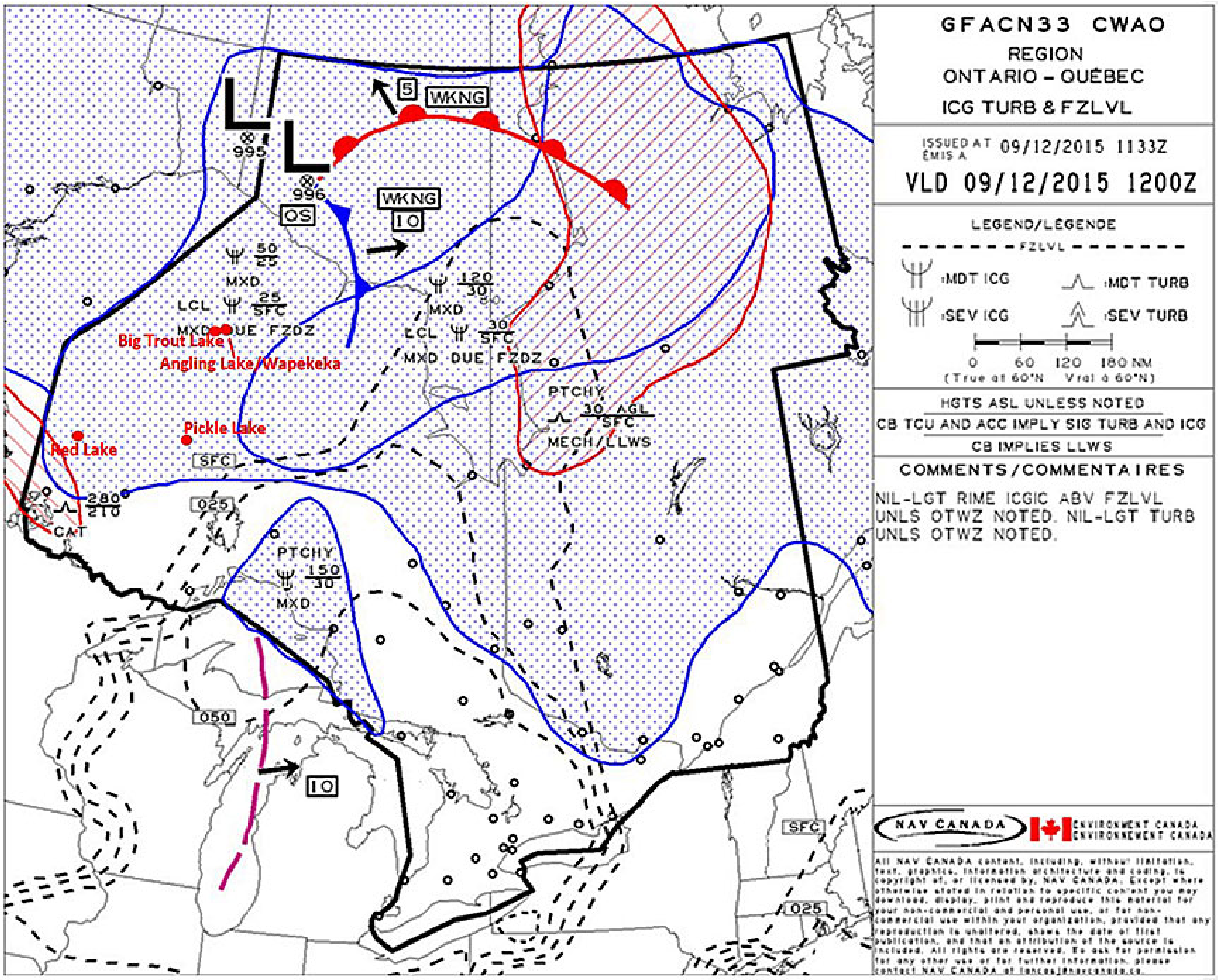


Source: U.S. National Transportation Safety Board.

Appendix F – Graphical area forecast CN33 valid at 0700 EST (1200 UTC) 09 December 2015

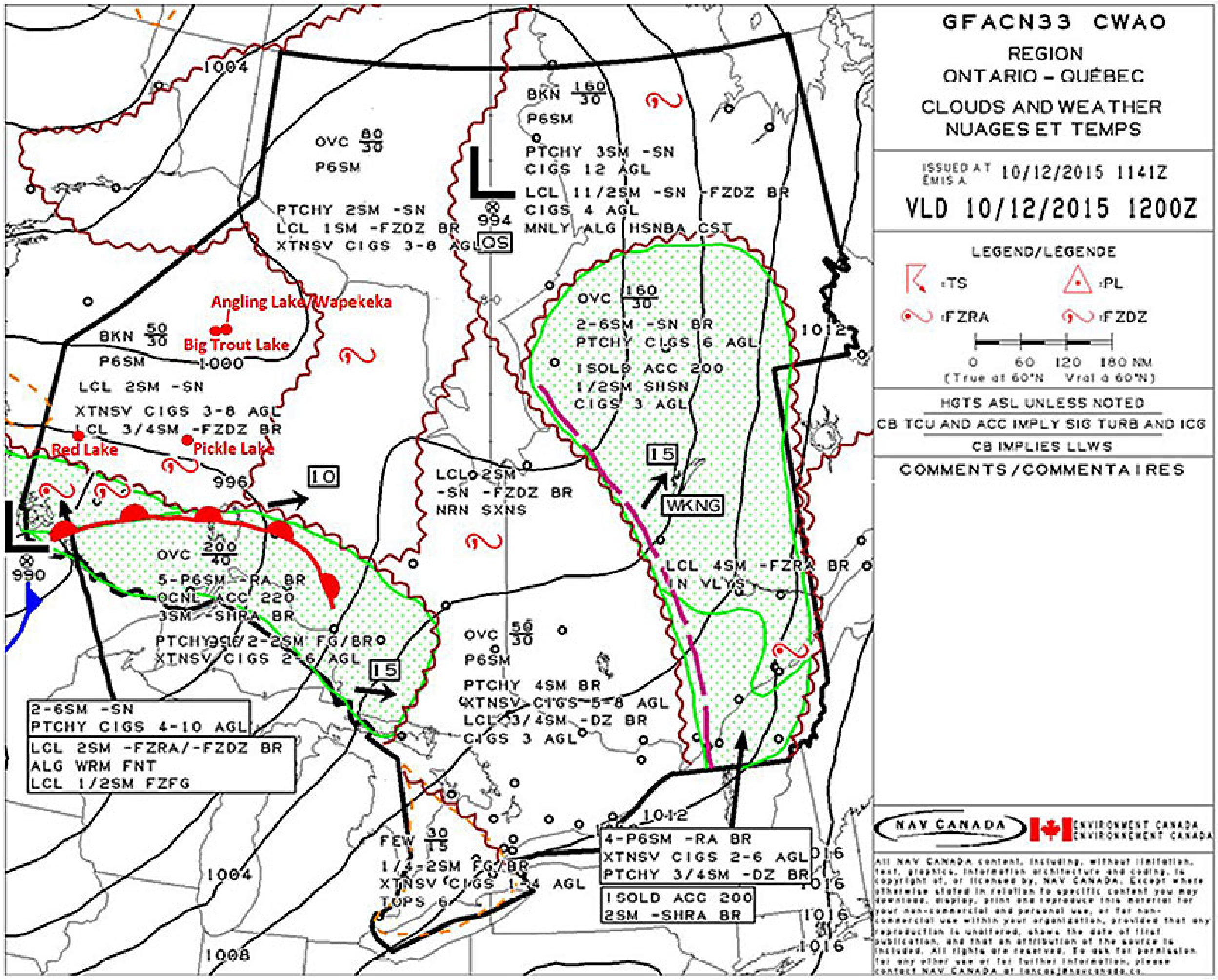


Source: NAV CANADA and Environment Canada.

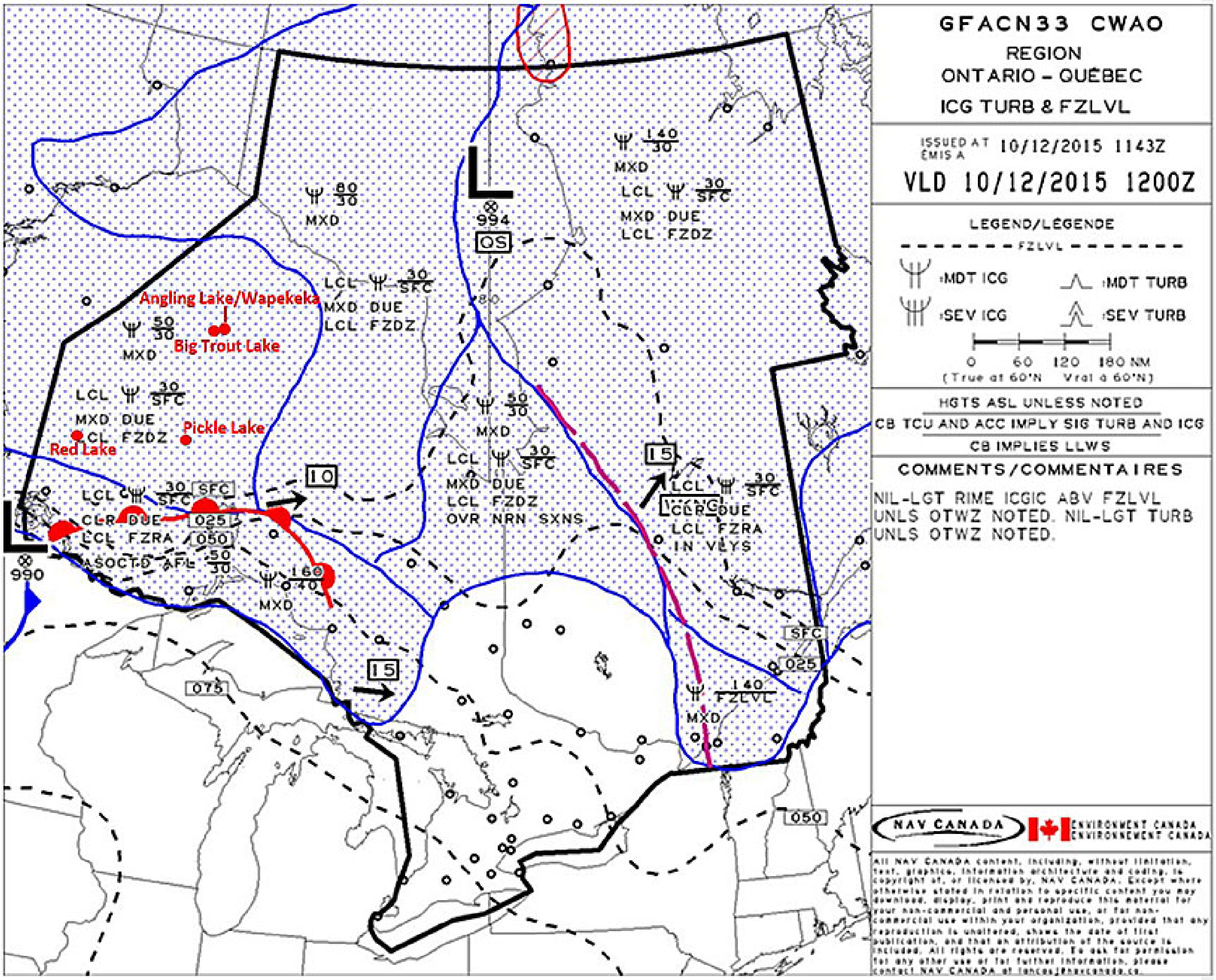


Source: NAV CANADA and Environment Canada.

Appendix G – Graphical area forecast CN33 valid at 0700 EST (1200 UTC) 10 December 2015

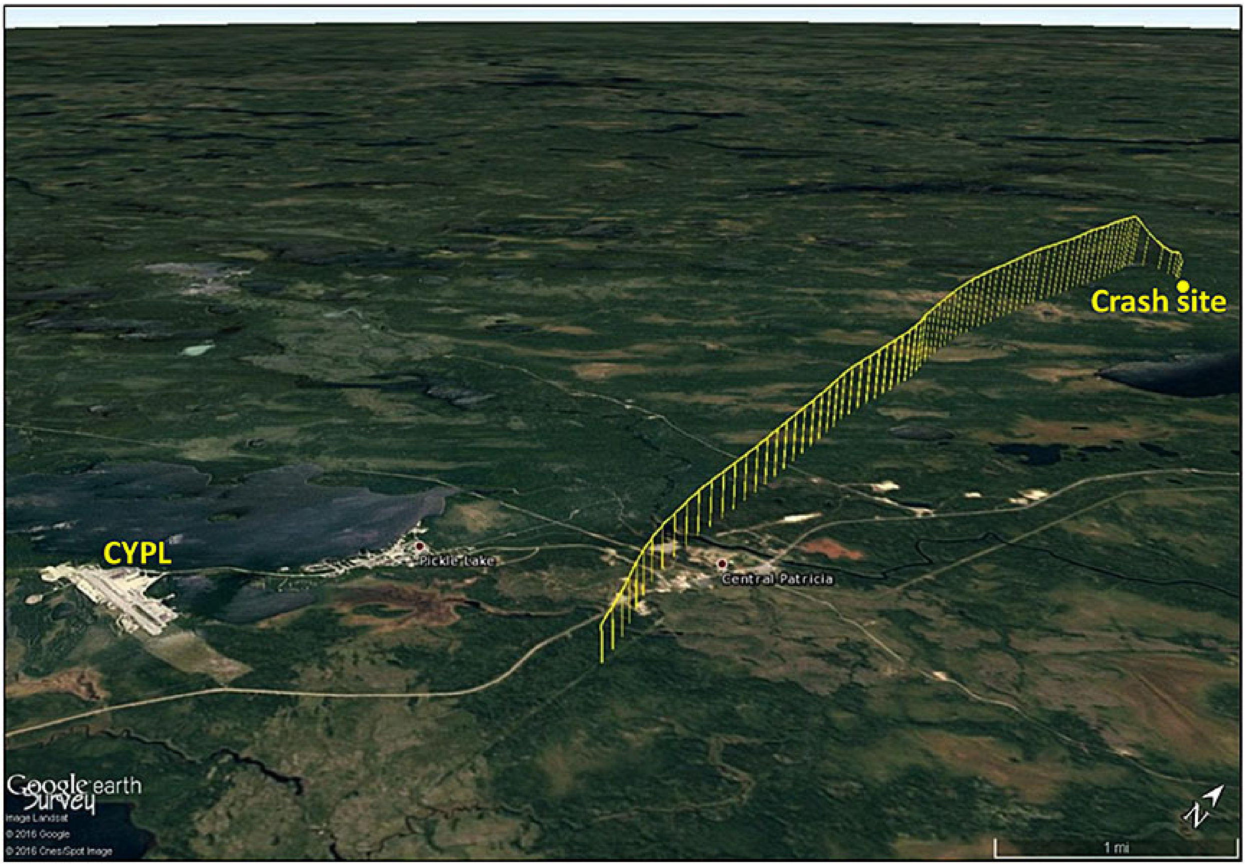


Source: NAV CANADA and Environment Canada.



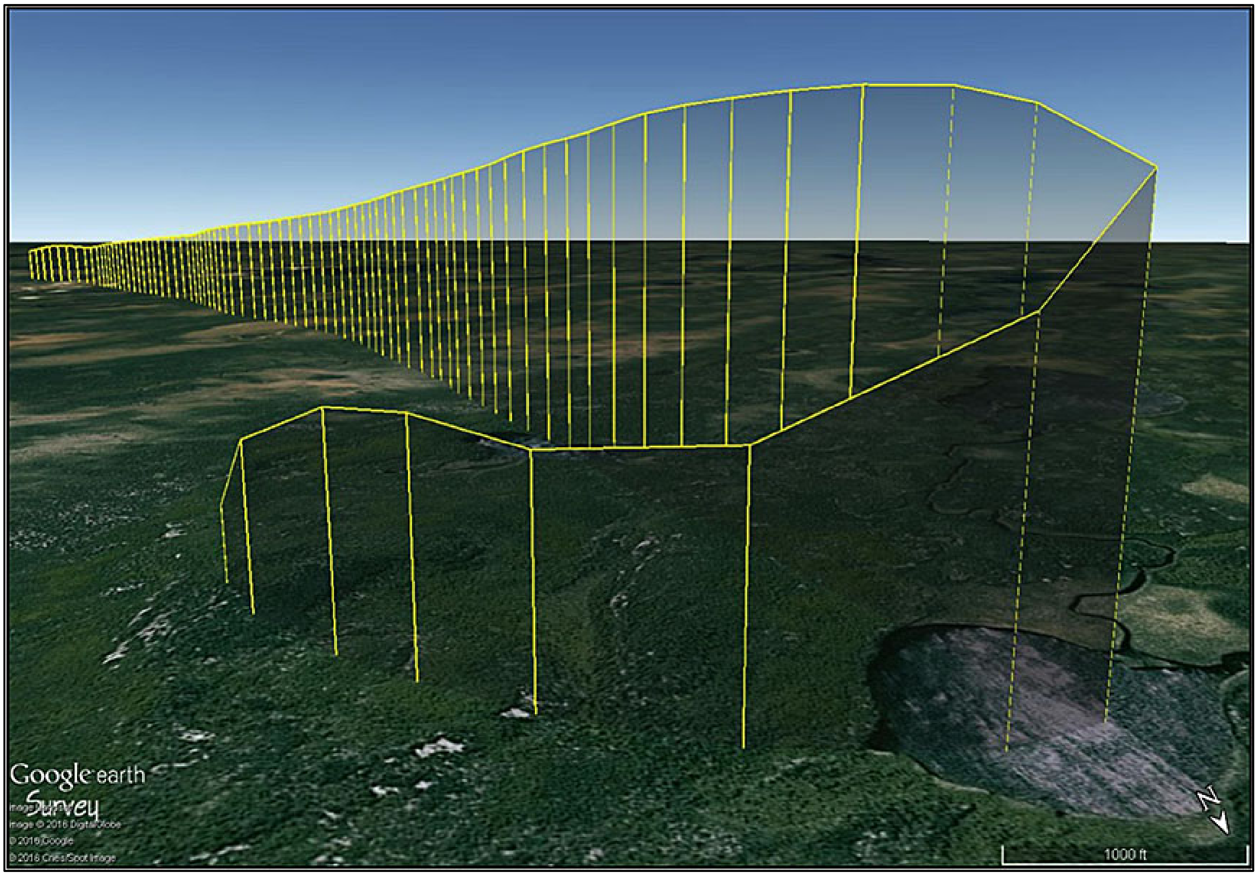
Source: NAV CANADA and Environment Canada.

Appendix H – Recorded flight path of flight WSG127



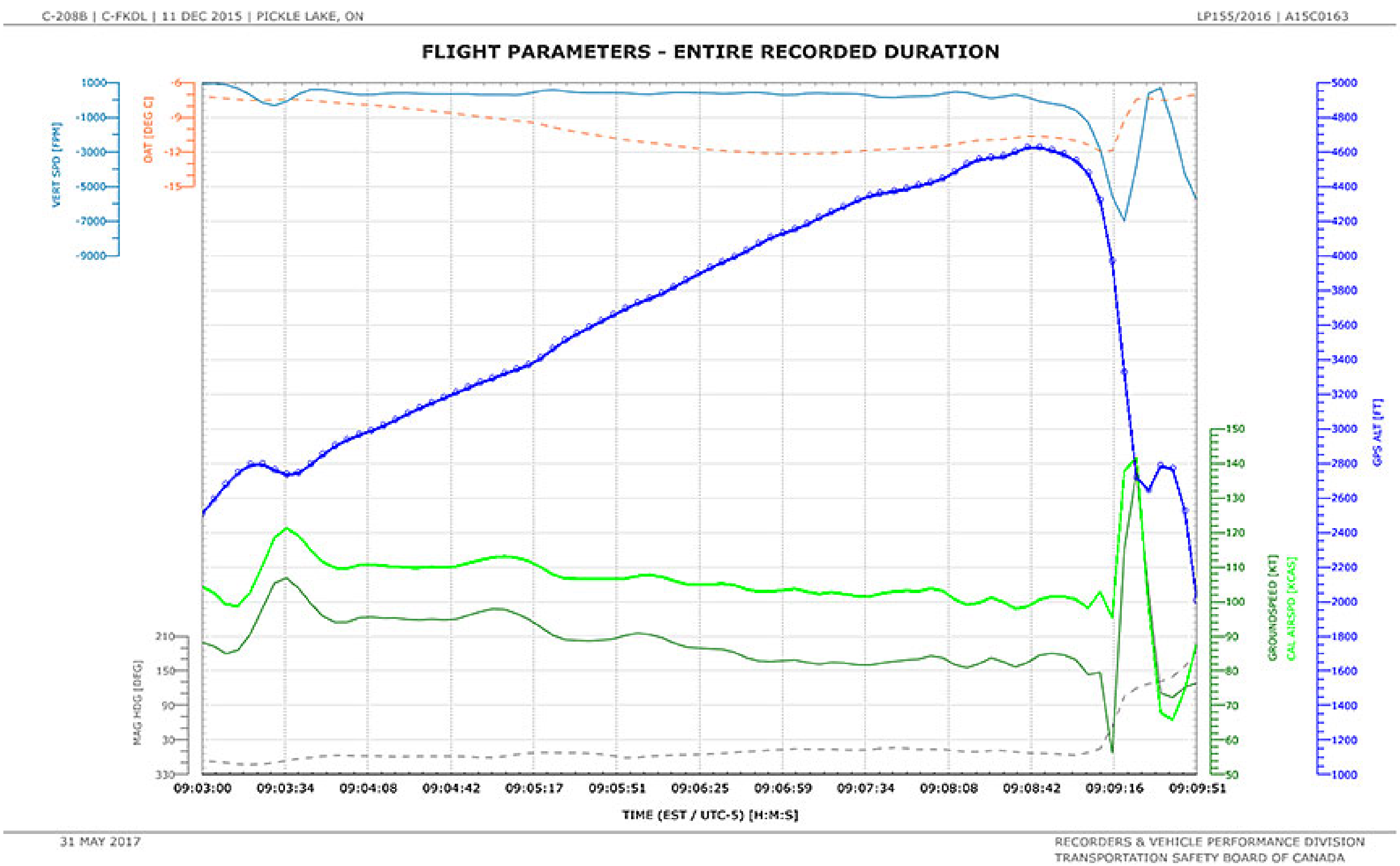
Source: Google Earth, with TSB annotations, from ISAT-100 satellite flight tracking system data.

Appendix I – End of recorded flight path for flight WSG127

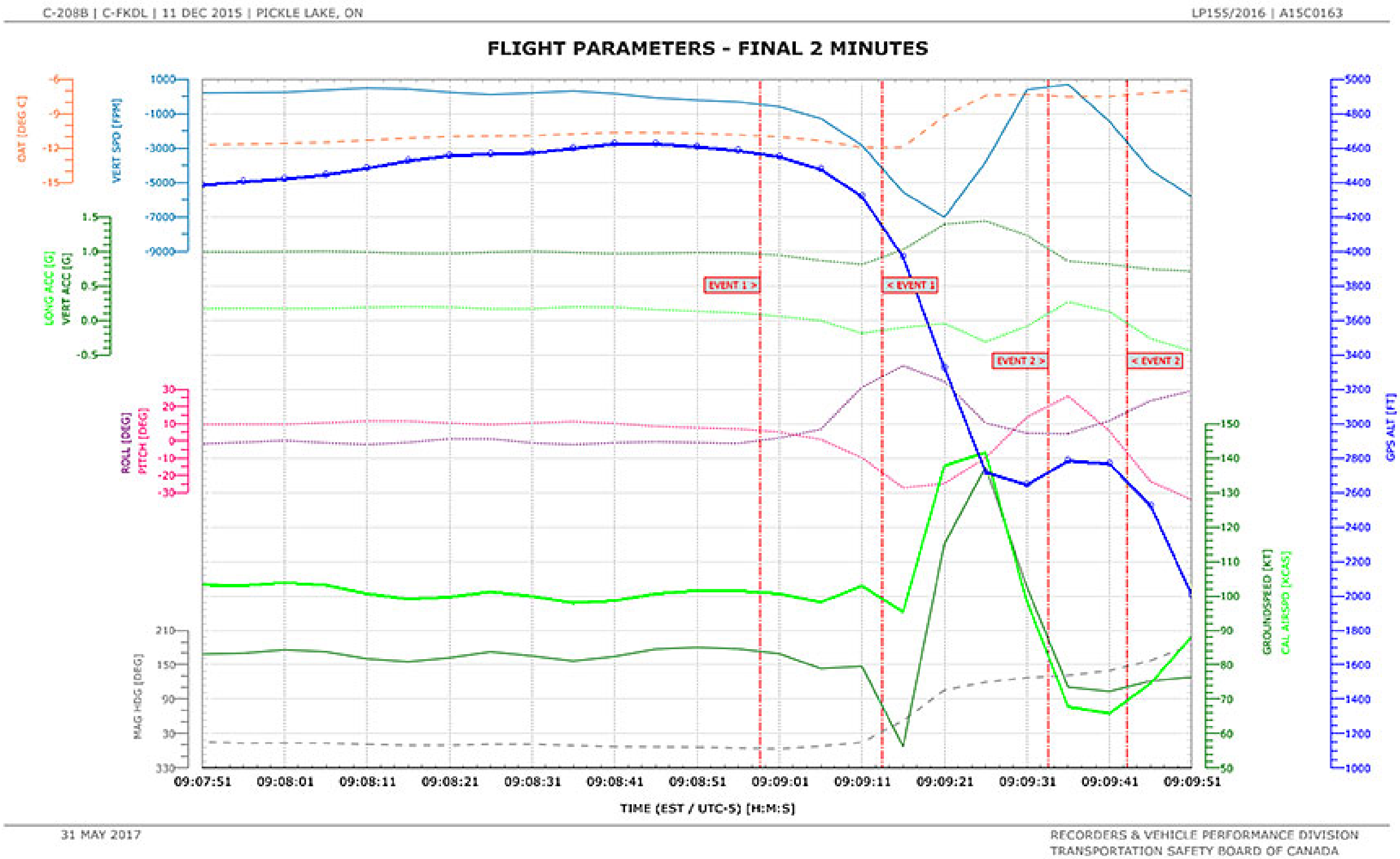


Source: Google Earth, with TSB annotations, from ISAT-100 satellite flight tracking system data.

Appendix J – Flight parameters for flight WSG127: entire recorded duration



Appendix K – Flight parameters for flight WSG127: final 2 minutes



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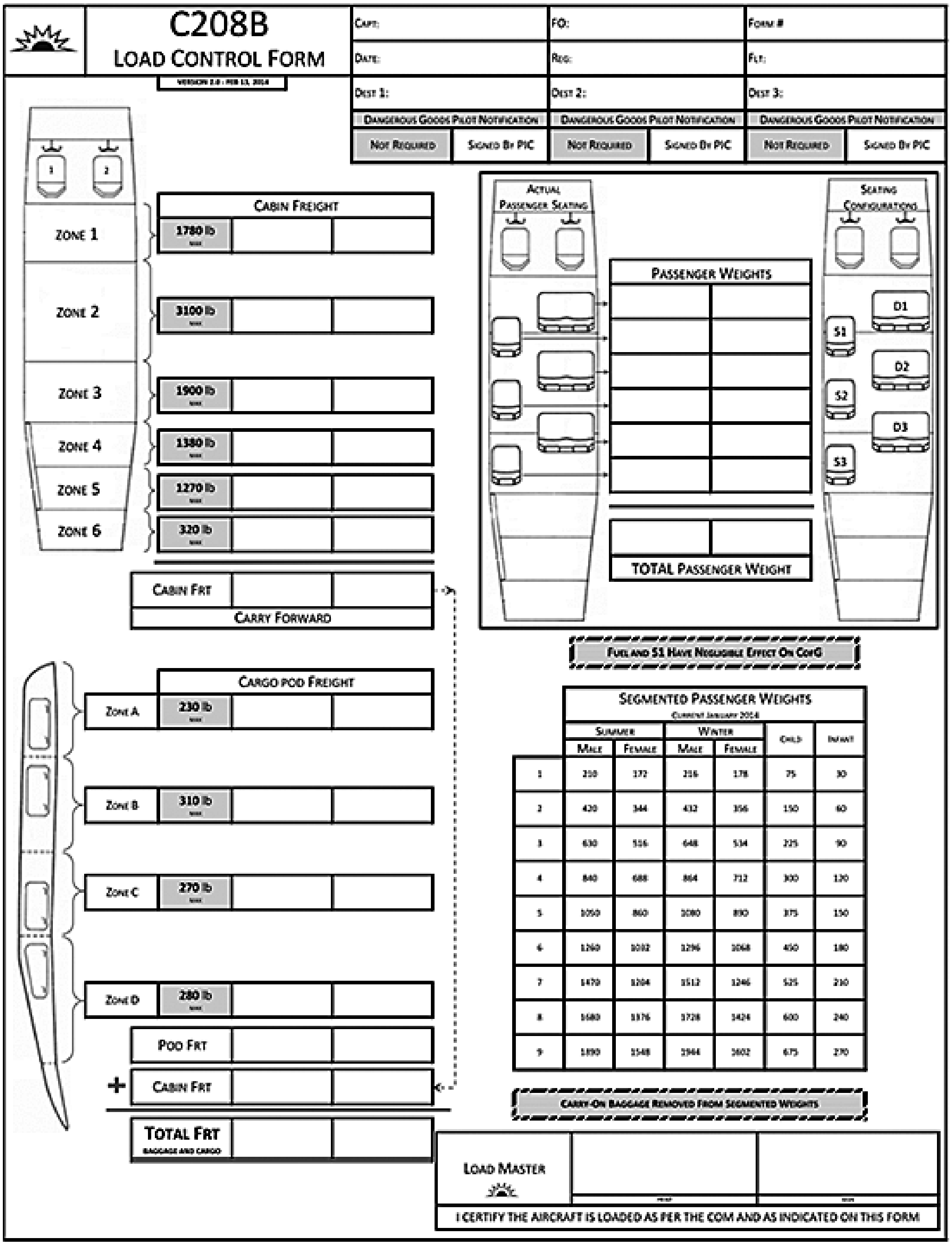
Appendix L – Wasaya Cessna 208B load distribution form



C208B
LOAD CONTROL FORM

Capt: | FO: | Form #
Date: | Reg: | Flt:
Dest 1: | Dest 2: | Dest 3:
Dangerous Goods Pilot Notification — Not Required / Signed By PIC

Cabin Freight
Zone 1 — 1780 lb
Zone 2 — 3100 lb
Zone 3 — 1900 lb
Zone 4 — 1380 lb
Zone 5 — 1270 lb
Zone 6 — 320 lb
Cabin Frt — Carry Forward

Actual Passenger Seating
Passenger Weights
Total Passenger Weight
Seating Configurations
D1 D2 D3 S1 S2 S3

Fuel and S1 Have Negligible Effect On CofG

Cargo Pod Freight
Zone A — 230 lb
Zone B — 310 lb
Zone C — 270 lb
Zone D — 280 lb
Pod Frt
+ Cabin Frt
Total Frt (Baggage and Cargo)

Segmented Passenger Weights
Current January 2014

	Summer		Winter		Child	Infant
	Male	Female	Male	Female		
1	210	172	216	178	75	30
2	420	344	432	356	150	60
3	630	516	648	534	225	90
4	840	688	864	712	300	120
5	1050	860	1080	890	375	150
6	1260	1032	1296	1068	450	180
7	1470	1204	1512	1246	525	210
8	1680	1376	1728	1424	600	240
9	1890	1548	1944	1602	675	270

Carry-On Baggage Removed From Segmented Weights

Load Master
I certify the aircraft is loaded as per the COM and as indicated on this form

Note: Both this form and the form in Appendix M (weight and balance form) were called the “load control form.”
Source: Wasaya Airways Limited Partnership.

Appendix M – Wasaya Cessna 208B weight and balance form

WASAYA AIRWAYS LP

CESSNA C-208B CARAVAN LOAD CONTROL

DATE	A/C TYPE	A/C REG.	CREW

FROM / TO												
BASIC WT												
PERSONS ON BOARD WT.												
BAGGAGE & CARGO WT. (A)												
FUEL TANK EQUIP WT (B)												
WT. OFF SEATS (C)												
SURVIVAL EQUIPMENT (D)												
TOTAL OF A, B, C, D												
FUEL @ TAKE OFF WT.												
GROSS RAMP WT.												
GROSS TAKE OFF WT.												
FUEL BURN - OFF WT.												
LANDING WT.												
THE AIRCRAFT CARGO AND WEIGHT HAVE BEEN CHECKED AND ARE WITHIN LIMITS												

LOAD CONTROL INSTRUCTIONS (C - 208B)

1. FUEL TANK EQUIPMENT	250 LBS
2 SEATS	25 LBS EACH
3. SURVIVAL EQUIPMENT	50 LBS
4. OIL INCLUDED IN BASIC WEIGHT	
5. TOTAL BAGGAGE & CARGO WEIGHT MUST INCLUDE A, B, C, & D PRIOR TO LOG BOOK ENTRY	
6. PERSONS ONBOARD WIGHT INCLUDES CREW	
	C -208B
MAX. RAMP WEIGHT	9097 LBS
MAX. TAKEOFF WEIGHT	9062 LBS
MAX. LANDING WEIGHT	9000 LBS

AVERAGE PASSENGER WEIGHTS

SUMMER (MAR 15 - DEC 14)		WINTER (DEC 15 - MAR 14)
200 lbs	MALES (12 yrs & Up)	206 lbs
165 lbs	FEMALES (12 yrs & Up)	171 lbs
75 lbs	CHILDREN (2 yrs & Up)	75 lbs
30 lbs	** INFANTS** (0 less than 2 yrs)	30 lbs

* A group of large males, such as a football team, are to be accounted for separately at not less than 215 lbs. each.*

** Add in where infants exceed 10% of adults**

NOTE: Where no carry - on baggage is permitted or involved, the weights for males & females may be reduces by 13 lbs.

Effective Date: April 16. 2009

Note: Both this form and the form in Appendix L (load distribution form) were called the "load control form."
Source: Wasaya Airways Limited Partnership.

Appendix N – Example of pre-flight risk assessment decision support tool for use by commercial air operators (operating under Canadian Aviation Regulations *Subpart 703)*

Exemplar Air Taxi Risk Assessment Tool ***(0 = Low Risk 5 = High Risk)***

Captain		First Officer		Date	
Departure		Destination		Risk Value	Flight Value

Pilot Qualifications and Experience			
1	Captain with less than 100 hours on type	4	
2	First Officer with less than 100 hours on type	4	
3	Single Pilot Flight	5	
4	Captain with less than 25 hours in last 90 days	3	
5	First Officer with less than 25 hours in last 90 days	3	
6	Duty day greater than 12 hours without rest period	4	
7	Flight time greater than 8 hours in the duty day	3	
8	Crew prone rest 8/9/10 hours prior to the duty day	5/4/3	
		Total Factor Score - Section 1	

Operating Environment			
9	Best Approach is non precision and at night or weather below VFR	3	
10	Best approach is a circling approach and at night or weather below VFR	4	
11	No published approach and at night or weather below VFR	4	
12	Mountainous airport requiring specific arrival/departure procedure and wx below MSA	5	
13	Control Tower not available - Mandatory Frequency / Uncontrolled Airport	2/3	
14	Elevation of airport greater than 5000' MSL	3	
15	Wet runway/ Contaminated runway	2/3	
16	Winter operation	3	
17	Twilight operation	2	
18	Night operation	3	
19	Stopping distance greater than 80% of available runway	5	
20	Flight with less than 3 hours notice	3	
21	International operation	2	
22	No weather reporting at destination	5	
23	Thunderstorms at departure or destination	4	
24	Severe turbulence forecast or reported along route of flight	5	
25	Ceiling and visibility at destination less than 500' and 1SM	3	
26	Heavy rain at departure or destination	5	
27	Frozen precipitation at departure or destination	3	
28	Icing forecast or reported (moderate - severe)	5	
29	Surface winds greater than 30 knots	4	
30	Crosswind greater than 20 knots	4	
31	Runway breaking action less than good	5	
		Total Factor Score - Section 2	

Equipment			
32	Special flight permit operation	3	
33	Differed (Items related to safety of flight)	2	
34	Special flight limitations based on AFM equipment limitations	2	
		Total Factor Score - Section 3	

Total	

Flight risk assessment of 25 or greater requires Management approval

Signature Pilot in Command ____________________ Signature First Officer ____________________

Source: A Canadian air taxi operator.

Appendix O – Wasaya crew briefing checklist

CREW BRIEFING CHECKLIST

FLIGHT NUMBER:		DATE:		
CREW:		FLIGHT DISPATCHER:		

BRIEFING ITEM	COMPLETE		NOTES
	YES	NO	
WEATHER:			
* METAR/TAF * SIGMET/AIRMET * FD'S * GFA CLOUDS/WEATHER * GFA ICING/TURBULENCE			
NOTAM:			
* DEPARTURE * DESTINATION(S) * ALTERNATE(S) * RUNWAY CONDITIONS			
MEL STATUS:			
* MEL NUMBER * AFM SUPPLEMENT			
OFP:			
* PLANNED FUEL * ALTERNATE(S) * ALTITUDE * FLIGHT TIME * FILED?			
CREW REQUESTS:			

Source: Wasaya Airways Limited Partnership.

Appendix P – Glossary

AFM	*Airplane Flight Manual*
AGL	above ground level
AIRMET	short-term meteorological information intended primarily for aircraft in flight, to notify pilots of potentially hazardous weather conditions not described in the current area forecast and not requiring a SIGMET
APE	aircraft payload extender
ASEP	Automated Supplementary Enroute Weather Predictions
ASL	above sea level
CAP	corrective action plan
CARs	*Canadian Aviation Regulations*
CKB6	Angling Lake / Wapekeka Airport
CIP	Current Icing Product
COM	*Company Operations Manual*
CYPL	Pickle Lake Airport
CYQT	Thunder Bay Airport
CYRL	Red Lake Airport
CYTL	Big Trout Lake Airport
CYXL	Sioux Lookout Airport
DO	director of operations
ELT	emergency locator transmitter
EM	enhanced monitoring

FAA	Federal Aviation Administration
FDC	flight dispatch clearance
FDM	flight data monitoring
fpm	feet per minute
GFA	graphical area forecast
GPS	global positioning system
IFR	instrument flight rules
in. Hg	inches of mercury
KCAS	knots calibrated airspeed
KIAS	knots indicated airspeed
M	magnetic
METAR	routine meteorological report
MF	mandatory frequency
MHz	megahertz
nm	nautical miles
OFP	operational flight plan
PIC	pilot-in-command

POH	pilot's operating handbook
PVI	program validation inspection
SAR	search and rescue
SIGMET	significant meteorological information
sm	statute miles
SMS	safety management system
SOCC	system operations control centre
SOP	standard operating procedure
STC	Supplemental Type Certificate
T	true
TAF	aerodrome forecast
TC	Transport Canada
TCCA	Transport Canada Civil Aviation
VFR	visual flight rules