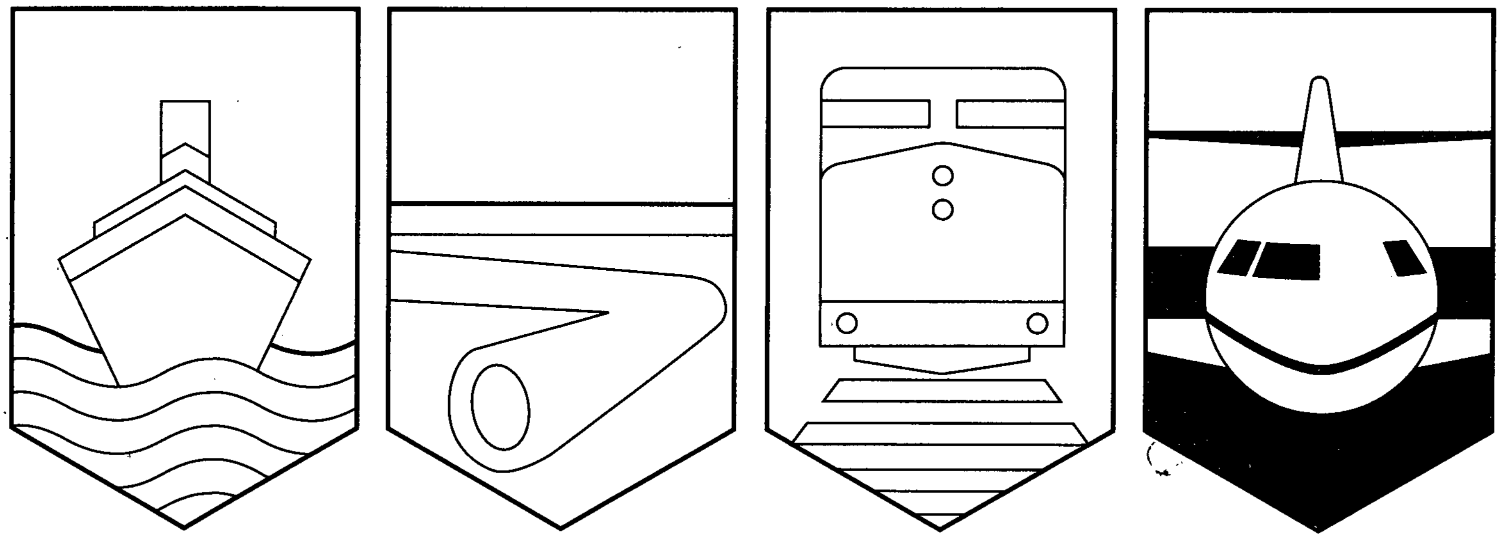
Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada



AVIATION OCCURRENCE REPORT

SIOUX NARROWS AIRWAYS LTD.
DE HAVILLAND DHC-2 MK. I BEAVER C-GUJY
TALTHEILEI NARROWS, NORTHWEST TERRITORIES
21 AUGUST 1989

REPORT NUMBER A89W0205

Canada

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

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TSB # 13/92

SIOUX NARROWS AIRWAYS LTD.
DE HAVILLAND DHC-2 MK 1 BEAVER C-GUJY
TALTHEILEI NARROWS, NORTHWEST TERRITORIES
21 AUGUST 1989

(To be released on 10 July 1992)

(Hull, Québec) - The Transportation Safety Board of Canada (TSB) has issued two aviation safety recommendations following its investigation into a fatal aircraft accident, 21 August 1989, near Taltheilei Narrows, on the north shore of Great Slave Lake, Northwest Territories.

The float-equipped de Havilland Beaver aircraft, belonging to Sioux Narrows Airways Ltd., had just taken off from a sheltered bay when it entered a left turn, pitched nose down, struck the water, and began to burn. The pilot and five passengers were fatally injured.

The Board determined that the aircraft stalled while attempting a downwind turn in conditions of severe wind shear. The pilot was unable to regain control of the aircraft before it struck the water.

The aircraft was not equipped with shoulder harnesses, nor was it required to be by regulation. One person died as a direct result of injuries caused by the impact and the others received incapacitating head injuries. The use of shoulder harnesses may have prevented the head injuries and provided a chance to escape from the semi-submerged aircraft. In view of the continuing number of fatalities caused by the absence or non-use of shoulder harnesses in Canadian small aircraft, the TSB recommends that:

> The Department of Transport expedite legislation to require the use of a seat-belt and shoulder harness during take-off and landing of small commercial fixed wing aircraft.

.../2

Present regulations require that emergency exits in transport category aircraft be clearly marked. The Beaver DHC-2 aircraft is exempt because it was initially manufactured before the existence of this rule. Kits for marking the exits are available for about $20 each. The Board feels that, in view of this low cost, the need for clear exit markings, the accident record, and the significant number of Beaver aircraft still in service, it should be mandatory to maintain exit markings in a legible condition and recommends that:

> The Department of Transport require that the exits of DHC-2 aircraft be marked clearly.

The Transportation Safety Board of Canada is an independent agency operating under its own Act of Parliament. Its sole aim is the advancement of transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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For further information:

Maryse Brunet-Lalonde
Manager, Communications
(819) 994-8051

Ghislain Charron
Public Affairs Officer
(819) 953-7812

Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

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

Aviation Occurrence Report

Sioux Narrows Airways Ltd.
de Havilland DHC-2 MK. I Beaver C-GUJY
Taltheilei Narrows, Northwest Territories
21 August 1989

Report Number A89W0205

Synopsis

After taking off from a sheltered bay, the float-equipped aircraft entered a left turn, pitched nose-down, struck the water, and burned. The pilot and five passengers died.

The Transportation Safety Board of Canada determined that the pilot stalled the aircraft while attempting a downwind turn in conditions of severe wind shear, and he was unable to regain control of the aircraft before it struck the water.

14 May 1992

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The float-equipped Beaver aircraft, with only the pilot on board, departed a fishing lodge located at Taltheilei Narrows, Northwest Territories on the north shore of Great Slave Lake, and flew to a sheltered bay 10 nautical miles (nm)[1] southwest of the lodge. The pilot landed, and five sports-fishermen boarded the aircraft from a group of small fishing boats. The passengers were to be flown to Yellowknife, Northwest Territories, a distance of 80 nm. A second float-equipped aircraft, loaded with the fishermen's baggage, circled overhead. The Beaver was observed to back-track toward the entrance to the bay, then turn and take off in a northeasterly direction.

After lift-off, the Beaver was seen to climb to an estimated height of 100 to 200 feet above the water surface, then enter a left turn, descend, and strike shallow water near the shore in a steep, nose-down, left-wing-low attitude. On impact with the water, both wings separated from the fuselage. Black smoke and fire were observed coming from the fuselage area. The pilot of the second aircraft attracted the attention of the fishing guides in the boats, who rushed to the accident scene. When the second aircraft landed in the bay, the fire was well developed and had enveloped the right side of the fuselage, which was above the water level. The pilot and five passengers died.

The accident occurred at 1105 mountain daylight time (MDT)[2] at latitude 62° 26'N, longitude 111° 38'W[3], during the hours of daylight, at an elevation of approximately 514 feet above sea level (asl).

[1]See glossary for all abbreviations and acronyms.
[2]All times are MDT (Coordinated Universal Time (UTC) minus six hours) unless otherwise stated.
[3]Units are consistent with official manuals, documents, reports and instructions used by or issued to the crew.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	1	5	—	6
Serious	—	—	—	—
Minor/None	—	—	—	—
Total	1	5	—	6

1.3 Damage to Aircraft

The aircraft was substantially damaged by impact and fire.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

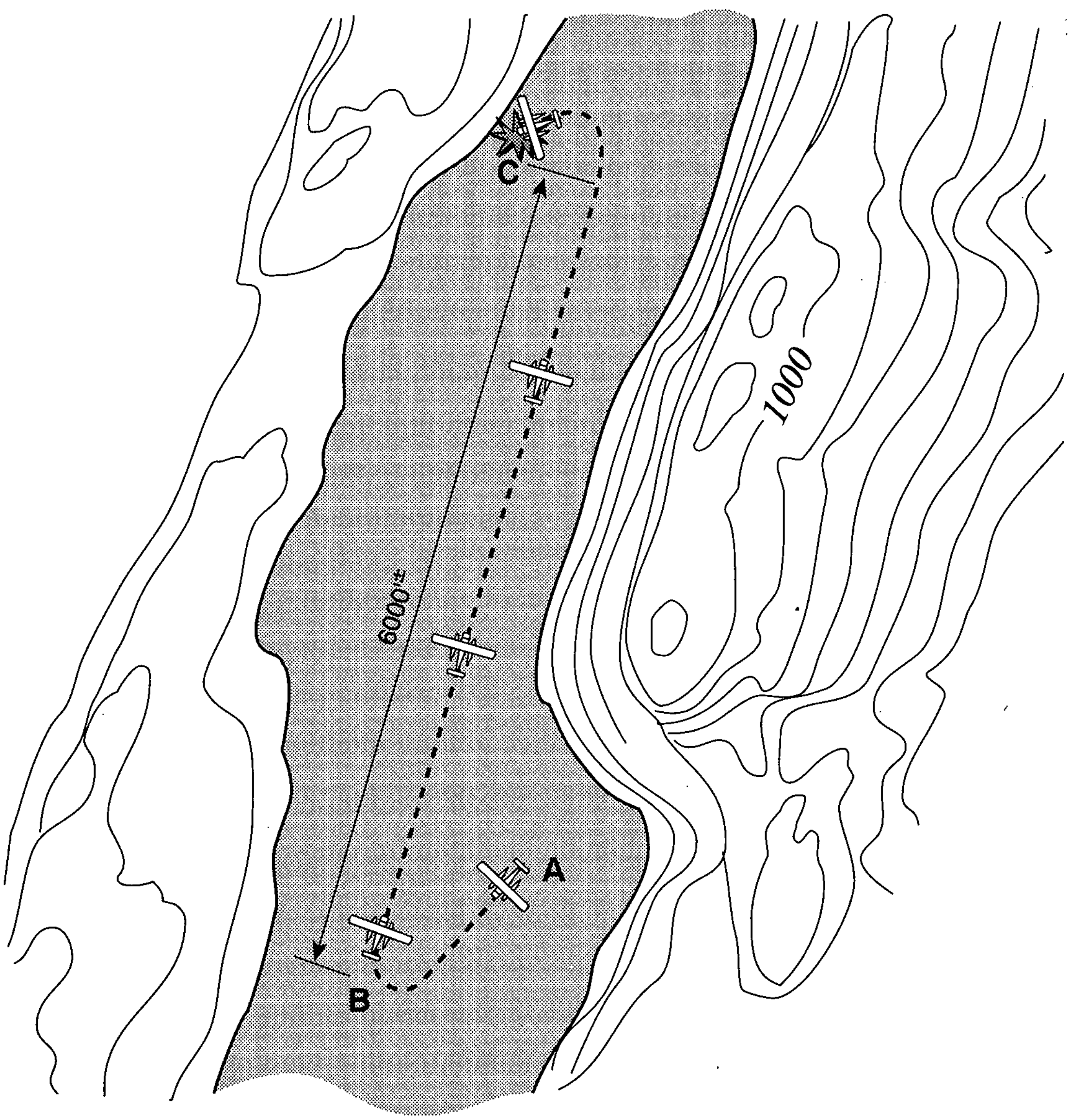
	Pilot-In-Command
Age	27
Pilot Licence	Senior Commercial
Medical Expiry Date	Valid
Total Flying Time	2,026 hr
Total on Type	789 hr
Total Last 90 Days	186 hr
Total on Type Last 90 Days	159 hr
Hours on Duty Prior to Occurrence	1 hr
Hours off Duty Prior to Work Period	70 hr

PLAN VIEW OF ACCIDENT FLIGHT

A Passengers boarded the aircraft from fishing boats.

B Approximate start of take-off run.

C Crash site 60 feet from shore line.



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The pilot held a Class I, Group I multi-engine instrument rating and was endorsed for single- and multi-engine land and sea planes. He was issued a Category I medical with no waivers or limitations.

The pilot had been employed by commercial operators in Manitoba and the west coast of British Columbia flying float-equipped Beaver aircraft. The pilot's training records and files did not reveal any deficiencies pertinent to this occurrence. It was reported that this was the first time the pilot had flown into the bay where the accident occurred.

1.6 *Aircraft Information*

Manufacturer	de Havilland of Canada
Type	DHC-2 MK. I Beaver
Year of Manufacture	1952
Serial Number	393
Certificate of Airworthiness	Issued 10 June 1983
Total Airframe Time	6,488 hr
Engine Type (1)	Pratt & Whitney R-985
Propeller Type (1)	Hamilton Standard
Maximum Allowable Take-off Weight	5,090 lb (on floats)
Recommended Fuel Type	80/87 Avgas
Fuel Type Used	100/130 Avgas

The company seasonally employed a qualified aircraft maintenance engineer (AME) to service and maintain aircraft at the fishing lodges. A 600-hour inspection had been certified in the aircraft logs on 19 August 1989. The flight from the lodge was the first trip after completion of the inspection. The 600-hour inspection is the equivalent of a 100-hour inspection with the addition of extra items.

1.6.1 *Weight and Balance*

The current weight and balance report prepared for this aircraft and filed with Transport Canada (TC) contained a number of errors which rendered the document unusable. The distances used to establish the scale locations during the weighing process on floats were measured from a non-standard reference datum. The front of the propeller hub was used as a datum, rather than the approved method of 100.0 inches in front of the original datum (17.5 inches aft of the wing leading edge).

An examination of the weighing process and the records determined the cause of the errors. A recalculation using correct arms resulted in usable data.

Based on the information available, it was estimated that the aircraft was at or under maximum gross weight at the time of the occurrence, and that the centre of gravity (C of G) was at or near the aft limit.

1.6.2 *Aircraft Handling Characteristics*

The manufacturer's Flight Manual states that the best rate-of-climb speed is 80 mph indicated airspeed (IAS). During the course of the investigation, several experienced DHC-2 pilots commented on the handling characteristics of the seaplane during left turns at speeds below 80 mph. They indicated that, once established in the left turn, it can be difficult to level the wings because of what they believe to be engine torque effects.

It could not be determined how the pilot planned to fly out of the bay after take-off. The choices included a 90-degree left turn over the rocky point on the west side of the bay, a 180-degree left turn back toward the entrance to the bay, or a climb-out straight ahead. It was determined that the turning radius of the seaplane at 80 mph, while in a coordinated 30-degree angle of bank turn, is 800 feet (a 1,600-foot diameter).

1.6.3 Auxiliary Vertical Stabilizer

The aircraft was equipped with Edo 679-4930 floats approved under Supplemental Type Certificate (STC) 1913WE, and auxiliary vertical seaplane fins were installed on the tips of the horizontal stabilizer.

The installation of larger floats places additional keel area ahead of the C of G, thereby reducing aircraft directional stability. The purpose of auxiliary vertical stabilizers is to improve the aircraft's directional stability characteristics.

It was determined that the auxiliary vertical seaplane fins were installed on the aircraft in 1988. However, no log entries referring to this installation were found. No evidence was found to indicate the manufacturer of the fins. Although the fins were similar in appearance to the type manufactured under STC SA456NW, examination by the TSB Engineering Laboratory determined that the material composition and thickness were not in accordance with the STC specifications.

Flight testing conducted by the Federal Aviation Administration (FAA) and TC determined that the directional stability of the aircraft with Edo 679-4930 floats and the STC approved auxiliary vertical seaplane fins met regulatory requirements. However, it could not be determined if the fins found on the aircraft would meet the directional stability requirements. Because the fins found on the aircraft were not an approved installation, the aircraft would not comply with TC Airworthiness Directives (ADs) CF-76-15 and CF-83-09R1.

1.6.4 Airworthiness Directives

Although not considered to be a factor in this occurrence, it was determined that several ADs had not been entered in the aircraft logs within the mandatory compliance times, as required by regulation. It could not be determined if the ADs had been complied with.

1.6.5 Aircraft Modifications

The aircraft had been fitted with large cabin side-windows, bubble-type cabin door windows, a fishing rod storage compartment, and a metal flush-mounted under-floor survival box. Details concerning these modifications were not recorded in the aircraft logs, and the weight and balance equipment list had not been amended to include these items, as required by regulation.

1.6.6 Aircraft Fuel Quantity

No evidence was found to determine the amount of fuel contained in the aircraft prior to departure from the fishing lodge. The fuel dispensing equipment at the lodge was not fitted with a recording meter, and a fuel log was not maintained. No entries were found in the aircraft logs to indicate the total amount of fuel on board for this trip.

No witnesses to the refuelling of the aircraft on the day of the accident were located. It was common practice at the lodge to carry only the amount of fuel (plus suitable reserves) required for the flight to Yellowknife, where the aircraft would be refuelled for the return trip. The reason for this practice was to conserve the fuel supplies at the remote lodge location. The minimum fuel required for the trip to Yellowknife was estimated at 40 imperial gallons. The typical loading of this amount of fuel, according to other Beaver pilots, would have been front tank full and centre tank approximately half full.

1.6.7 *Aircraft Stall Speeds*

The aircraft Flight Manual states that the seaplane wings-level stall speed is 60 mph at maximum gross weight (5,090 pounds). Data obtained from the manufacturer indicate a stall speed of 61 mph at maximum gross weight, while in a 30-degree bank with climb flap. All stall speeds given are for the power-off condition.

1.7 *Meteorological Information*

A witness at the accident site reported that the skies were clear with gusty winds from the east. Weather observation facilities are located at Fort Reliance, approximately 60 miles east, and at Yellowknife, 80 miles west of the accident site.

An analysis of the weather conditions conducted on behalf of the TSB by the Atmospheric Environment Service (AES) of Environment Canada concluded the following:

> For the period in question, a high pressure area was centered about 60 miles east of Bathurst Inlet with ridges extending northward to Victoria Island and southward to northwestern Saskatchewan. The high cell was building very slowly to the southeast. At the same time a trough of low pressure was observed from western Alberta to Great Slave Lake.
>
> The 211200Z (Zulu time) and 211800Z surface analyses indicated a southeast gradient of 20 to 25 knots. The surface observation from Yellowknife indicated an east wind of 15 knots. A gust to 21 knots was reported at 1600Z. The few reports from Fort Reliance indicated winds were likely easterly at about 15 knots. Although the observed winds were light to moderate easterly in the surrounding area, it is likely that stronger terrain-induced winds occurred at various locations over the east arm. A moderate to strong easterly flow over the Pethei Peninsula could very well produce some strong down drafts to the west of it.

Terrain-induced winds result when the air flow increases in speed over a topographical feature such as a cliff.

During the investigation, similar winds were observed at the site, resulting in turbulence and horizontal wind shear on the lee side of the 500-foot cliffs bordering the bay.

1.8 *Aids to Navigation*

Not pertinent.

1.9 *Communications*

The pilot was in radio communication with the second aircraft circling over the site. The pilot did not advise of any problem prior to impact with the water.

1.10 *Aerodrome Information*

Not pertinent.

1.11 *Flight Recorders*

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR), nor was either required by regulation.

1.12 *Wreckage and Impact Information*

1.12.1 *Accident Site*

The accident site was located in a sheltered bay near the northeast shore of Great Slave Lake, 10 nm southwest of the fishing lodge at Taltheilei Narrows. The 3.5-mile long bay is oriented in a northeast/southwest direction with the southwest end open to Great Slave Lake. A steep cliff, rising to approximately 500 feet above the water, faces the east side of the bay. A tree-covered rocky point, about 200-feet high, faces the west side of the bay. The width of the bay at the accident site was approximately 1,670 feet; at 100 and 150 feet above the water surface the width is approximately 2,110 and 2,310 feet respectively. The landing and subsequent take-off were toward the closed end of the bay, into wind. The aircraft came to rest on a heading of 275 degrees magnetic, 60 feet from the west shore in four to six feet of water.

1.12.2 *Aircraft Wreckage*

The fuselage was lying on its left side with the entire right side burned away back to the baggage compartment. The left-hand float was torn in half, and the sections had sunk beside the fuselage. The right-hand float was bent upwards and remained floating beside the fuselage, attached by damaged fittings.

The wings, complete with lift struts, had separated on impact and were lying on the bottom. Numerous smaller parts of the aircraft, which had torn off during impact, had sunk to the bottom of the bay. Measurements indicate that the aircraft struck the water in a 60-degree nose-down, 22-degree left-wing-low attitude.

When the wreckage was raised, the engine appeared to be relatively undamaged. The wreckage was brought up on the shore for detailed examination and later transported to the lodge where it was to be held in quarantine.

All major components were located and recovered. Examination established continuity of all flight controls; there was no evidence of mechanical discrepancies prior to impact.

The wing flaps were determined to be in the climb position at impact.

Discoloration was evident on the left landing gear and wing strut fitting assembly fracture surfaces when the aircraft was recovered. The TSB Engineering Laboratory examination determined that both the left and right landing gear and wing strut fittings failed as a result of severe overload, with no pre-cracking evident. The darker coloration on the left fitting fracture surface was attributed to environmental exposure.

1.12.3 *Engine Examination*

The engine was taken to a test facility. Water was removed from the magnetos and ignition wiring, and the engine was successfully test run. The engine was capable of normal power output. The carburettor throttle butterfly was trapped in the idle position;

the body of the carburettor had been distorted at impact.

1.12.4 Propeller Examination

The propeller blades were bent rearwards, with one blade having a more pronounced bend than the other. The propeller blades had contacted the shallow mud bottom of the bay during the impact sequence. The leading edges of the blades were only lightly nicked, and there was little evidence of rotational scoring on the faces of the blades. There was no evidence of the torsional distress in the blades, which is commonly seen when the engine is at a high power setting at impact.

A teardown examination was conducted, and it was determined that the propeller blades were in full-fine pitch at impact.

1.12.5 Instrument Examination

Examination of the flight and engine instrument panels by the TSB Engineering Laboratory determined the following impact indications/settings/selections:

a) fuel pressure – 5 pounds per square inch (psi) (normal range: 3 to 5 psi)
b) oil temperature – 60 degrees Celsius (normal range: 40 to 85 degrees Celsius)
c) cylinder head temperature – 85 degrees Celsius (normal range: 100 to 250 degrees Celsius)
d) fuel pressure warning light – on, but considered to have most likely illuminated at impact. This light normally illuminates when the fuel pressure drops below 3 psi. Laboratory analysis concluded that this light probably illuminated during the impact sequence and was not indicative of a fuel pressure problem prior to impact.
e) fuel selector handle – on front tank
f) magneto switch – on both

The tachometer, fuel quantity gauge, manifold pressure, oil pressure, exhaust gas temperature, and airspeed indicator did not provide any reliable information as to their indication at impact.

1.12.6 Fuel Selector

The fuel selector handle, located on the lower left side of the pilot's instrument panel, was found in the front tank position. The cable-operated fuel selector valve, located at the rear of the fuel tanks, had been subjected to fire damage and was torn from its mounting bracket during the impact sequence. Examination indicated that the valve had rotated to a position between two tank selections, possibly as a result of cable movement from airframe distortion at impact.

1.12.7 Exhaust Stack

A comparative metallurgical examination of crushed sections of the exhaust stack suggests that the material was at lower-than-normal operating temperatures at impact. Although this evidence is considered to be a good indicator of engine condition at impact, it is not considered definitive or a matter of absolute fact, since it is based on an as yet unproven experimental investigative technique.

1.13 Medical Information

The occupants remained in the cabin and were removed by the coroner. Autopsy information indicates that pilot incapacitation was not a factor in the occurrence. Toxicological tests on the pilot indicate the presence of therapeutic levels of non-prescription antihistamine and a trace of an oral decongestant. Although drowsiness is a known side effect of such medications in some individuals, the effect on the pilot could not be determined.

All of the occupants received head injuries. Autopsy reports indicate that the passenger seated in the front right (co-pilot's) seat died as a result of multiple injuries. The other two passengers seated on the right side died of anoxia and inhalation of superheated gas. All of the occupants seated on the left side of the aircraft, including the pilot, died of drowning. With the exception of the passenger in the front right seat, the injuries received by the occupants would have been considered survivable.

1.14 Fire

Observers indicated that the right-hand cabin section of the fuselage was engulfed in flames after impact. The fuselage was lying on its left side in four feet of water and was burned from the firewall to the aft cabin bulkhead, including the right cockpit door, the right cabin door, and a section of the cabin floor. The right sides of all three metal fuselage fuel tanks were melted and the interior was exposed. There was no evidence of a pre-impact fire. The engine fire bottle had not been discharged. The main electrical cable from the battery, which is routed down the lower right side of the fuselage, displayed a prominent kink adjacent to the upper middle float strut fitting. This float fitting was torn out during the impact and was located between the fuel tanks.

1.15 Survival Aspects

The aircraft was not fitted with shoulder harnesses. All of the seat-belt buckles were found latched. One seat-belt fitting in the centre row of seats had failed in overload. A number of unopened life preservers were located in the cabin.

Although not required by regulation, exit signs and placards describing the method of opening the doors, as described in de Havilland Service Bulletin 2/45, were not found on the interior of the pilot's or the main cabin doors. The placard kit had been ordered by the operator, but had not been received at the time of the occurrence.

The emergency locator transmitter (ELT), located behind the passenger cabin, was examined by the TSB Engineering Laboratory. It was determined that the ELT was in the armed position, but severe fire damage rendered it inoperable.

1.16 Tests and Research

1.16.1 Fuel and Oil Samples

Fuel samples taken from the aircraft and from the fuelling facility were submitted to the Alberta Research Council Laboratory for a gas chromatography analysis. The chromatographic profile obtained from both samples was typical of a grade 100 aviation gasoline.

An oil sample obtained from the engine oil sump was submitted to the same facility for spectrographic analysis and comparison with a new sample of the type of oil used by the operator. The sample was found to be typical of an aviation oil. The results of the spectrograph were recorded for future reference.

1.16.2 Centre Row Passenger Seat

An additional seat-belt was found attached to the inboard seat-belt fittings used on the original military seats. The seat-belt fitting located on the inboard side of the right seat had failed during the accident sequence.

The TSB Engineering Laboratory examination determined that, although the additional seat-belt was not an approved installation, it was not in use at the time of the accident and would not have any bearing on the fitting failure. The design strength of the fitting lug exceeded the requirements for a one-occupant restraint, and calculations indicate that the load factor applied during impact exceeded that necessary to fail the fitting.

1.16.3 Observation Flight

An observation flight with a similarly equipped Beaver aircraft on floats was conducted when the wind conditions (east at an estimated 15 knots with gusts to 20) were similar to the reported winds on the day of the accident. The flight was conducted with two occupants in the aircraft. A climb was initiated commencing at an approximate point where the accident flight would have lifted off the water. Because of the gusty wind conditions, a climb speed of 100 mph was used rather than the recommended 80 mph to provide a safety margin. The objective was to climb until abeam the accident site and then turn 90 degrees to the left, downwind, at 30 degrees of bank and monitor the airspeed and the altitude change. A turn was initiated abeam the accident site at a height of 200 feet, and, as the turn progressed through 60 degrees, the airspeed decreased, and the aircraft started to settle. The nose was lowered slightly, and engine power increased to stabilize the airspeed at 75 mph and minimize the altitude loss to 100 feet while returning to level flight. The aircraft was slow to roll out of the turn and nearly full deflection of both rudder and aileron was required to return the aircraft to level flight. Light to moderate turbulence was encountered during the flight.

1.16.4 Test Flight

A TC flight test in August 1990 confirmed that the directional stability of the aircraft with Edo 4930 floats and tip fins satisfied the requirements of British Civil Aviation Regulations (BCAR) Section D and Civil Aviation Regulations (CAR) 03 dated 1949.

1.17 Additional Information

1.17.1 Transport Canada Airworthiness Inspection

In August 1988, the aircraft and log-books were inspected by a TC Airworthiness Inspector. No defects were recorded with either the aircraft or log-books. Examination of the aircraft and log-books by TSB investigators determined that, at the time of this inspection, the following conditions existed:

a) Several modifications to the aircraft had been accomplished without the required entries having been made to the appropriate log-books;

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b) Applicable ADs had not been entered in the Journey Log as required by regulation;
c) Major errors existed in the aircraft weight and balance report, and;
d) Exit signs were missing from the aircraft.

1.17.2 *Reported Fuel Leak*

It was reported that, on a previous flight, a fuel leak was observed in the area of the fuselage fuel tank fillers. It was believed that this leak would occur after the tanks were refuelled to maximum capacity, as a result of seepage at the rubber connecter between the filler neck and the tank.

1.17.3 *Operations Manual*

The current Operations Manual, as issued by the operator and accepted by TC, indicates, under "Form Preparation" (5.1.4), that the following forms are to be prepared and carried on all company flights:

— Operational Flight Plan
— Maintenance Release
— Load Control Sheet (weight and balance)
— Fuel Release Slip (or method of certifying amount of fuel on aircraft)

No evidence was found to indicate compliance with the load control sheet or fuel release slip requirements of the Operations Manual.

2.0 *Analysis*

2.1 *Introduction*

The evidence indicates that the pilot lost control of the aircraft while in the left turn initiated shortly after lift-off. The steep, nose-down attitude at impact suggests that the aircraft stalled during the turn. The analysis will focus on possible aircraft malfunctions, weather conditions, and aircraft directional stability. Survival aspects, the source of the fire, and the adequacy of the TC Airworthiness Inspection conducted in August 1988 will also be discussed.

2.2 *Aircraft Malfunctions*

No pre-impact failures or malfunctions of the aircraft which could explain the apparent stall were identified. However, the minimal damage incurred by the propeller, the laboratory analysis of the crushed exhaust stack, and the impact reading of the cylinder head temperature gauge indicate that the engine was at low power when the aircraft struck the water. Thus, it is possible that a stall was precipitated by a loss in engine power during the turn and a rapid decrease in airspeed. However, no reason which could explain such a power loss could be found. The engine was successfully test run after the accident and found to be capable of producing normal power.

The throttle butterfly valve was found trapped in the idle position; thus, it is likely that the low power setting at impact was the result of the pilot closing the throttle prior to water impact.

2.3 *The Weather*

An analysis of weather conditions by AES specialists determined that, although observations at Yellowknife and Fort Reliance indicated that surface winds were easterly at 15 gusting to 21 knots, it was likely that stronger terrain-induced winds occurred at locations over the east arm of Great Slave Lake. This strong easterly wind, blowing over the steep cliffs facing the east side of the bay, would flow downwards with considerable force, creating eddies and turbulence in the flight path of the climbing aircraft. The effect of this subsiding air has been reported to result in downdrafts greater than 2,000 feet per minute, which have been known to exceed the climb performance of most general aviation aircraft. An upward vertical gust, caused by mechanical turbulence or eddies, causes an abrupt increase in angle of attack because of the change in direction of the air relative to the wing, and could result in a stall if the airspeed of the aircraft is relatively low.

The observation flight confirmed the adverse effect of this wind shear condition on the controllability of the aircraft. During the flight, a loss of 100 feet of altitude and 25 mph of airspeed occurred as the climbing aircraft turned downwind. The observation aircraft was operating at minimum weight and was climbing at 100 mph to provide a safety margin. If the pilot of the accident aircraft had been climbing at the recommended climb speed of 80 mph, in similar weather conditions when he turned downwind, the loss of airspeed and altitude would likely have resulted in a stall. The stall speed at maximum gross weight with the flaps in the climb position and 30 degrees of bank is 61 mph, 19 mph below the recommended climb speed. The altitude at which the stall occurred would have made recovery before water impact unlikely.

The likelihood of a stall would have been increased because of the terrain-induced turbulence and the possible use of bank angle greater than 30 degrees. It could not be determined by what route the pilot had planned to fly out of the bay after take-off. Depending on the altitude above the water surface when he commenced the turn, he would have had 1,500 to 1,600 feet in which to complete a 180-degree turn if he had intended to exit the bay at its mouth. The strong tail wind encountered during the turn would have significantly increased the turn radius beyond the still wind radius of 800 feet. Thus, the pilot may have increased the bank angle to complete the turn in the space available.

2.4 *Aircraft Directional Stability*

There was no direct evidence to indicate that degraded directional stability contributed to the accident. However, the auxiliary vertical seaplane fins found on the aircraft were not approved installations, and it could not be determined if they would meet the directional control requirements.

2.5 *Airworthiness Inspection*

The airworthiness inspection conducted by TC in 1988 did not identify discrepancies in the aircraft log-books and aircraft modifications, errors in the aircraft weight and balance report, and non-compliance with the AD requiring installation of an auxiliary ventral fin.

2.6 *Fire*

The short circuit that resulted from contact between the electrical battery cable and the float strut fitting was the likely ignition source of the post-impact fire.

2.7 *Survival Aspects*

There was no evidence that any of the occupants attempted to escape the aircraft. The head injuries described in the autopsy examination of the occupants would have resulted in temporary incapacitation. These head injuries may be related to the lack of shoulder harnesses in the aircraft, and may also explain why none of the seat-belt buckles had been unfastened.

3.0 Conclusions

3.1 Findings

1. The pilot was certified and qualified for the flight in accordance with existing regulations.
2. There was no evidence of any airframe failure or system malfunction prior to or during the flight found.
3. Based on the available information, it was determined that the weight and C of G were within limits.
4. The current weight and balance report prepared for this aircraft and filed with TC contained a number of errors which rendered the document unusable.
5. Terrain-induced winds at the time of the accident likely created significant wind-shear conditions, downdrafts, and turbulence.
6. The pilot stalled the aircraft while turning downwind after encountering the terrain-induced wind conditions.
7. The pilot was unable to regain control of the aircraft before it struck the water.
8. The occupants were unable to escape because of incapacitating head injuries during the impact.
9. The aircraft was not fitted with shoulder harnesses, nor were they required by regulation.
10. The exits were not marked.
11. The engine was at low power at impact for undetermined reasons.
12. Unapproved modifications had been incorporated on the aircraft.
13. Discrepancies in the aircraft log-books and aircraft modifications, and errors in the weight and balance report were not identified in TC's Airworthiness Inspection report.
14. No evidence was found to indicate compliance with the load control sheet or fuel release slip requirements of the Operations Manual.
15. The aircraft was not in compliance with AD CF-76-15 or CF-83-09R1, which required installation of an auxiliary ventral fin.

3.2 Causes

The pilot stalled the aircraft while attempting a downwind turn in conditions of severe wind shear, and he was unable to regain control of the aircraft before it struck the water.

4.0 Safety Action

4.1 Action Taken

4.1.1 Weight and Balance Data

During the investigation, it was noticed that the seat locations depicted in the Flight Manual were different from those in the Aircraft Type Approval (ATA) and Federal Aviation Administration (FAA) Aircraft Specification. The difference would not have altered the performance of the aircraft; however, to prevent any discrepancy in aircraft documentation which could lead to incorrect weight and balance computations, an Aviation Safety Advisory was sent to Transport Canada (TC). Apparently, the location depicted in the ATA is that of the centre of gravity (C of G) of the seat alone; whereas, the Flight Manual indicates the C of G of the occupant of the seat. Subsequently, to make the ATA consistent with the Flight Manual, the ATA was amended so that it, too, depicts the location of the C of G of the occupant.

4.1.2 Audit Inspection and Surveillance

A TC inspection of the aircraft about a year before the accident found no discrepancies with the aircraft or the log-books; however, several existed. Modifications had been accomplished without entries in the log-books, Airworthiness Directives (ADs) had not been entered in the Journey log, and major errors existed in the weight and balance report. Subsequent to an accident at Ross River, Northwest Territories in 1987 which showed similar oversights, the Canadian Aviation Safety Board (CASB) recommended that:

> The Department of Transport cause an independent study to be made of Transport Canada's policies and procedures for the audit, inspection and surveillance of the operations and maintenance functions of air carriers engaged in remote operations.
>
> CASB 89-05

The effectiveness of regulatory audit and surveillance by TC was also addressed by recommendations* which dealt with the follow-up of deficiencies discovered during previous audits and with the frequency of audits of operators with restricted Aircraft Type Approvals (ATAs).

Subsequent to these recommendations, TC indicated that recent changes in policy, as outlined in the new Manual of Regulatory Audits, scheduled for issue in 1991, would address the Board's concerns regarding the Department's conduct of surveillance, audit, and inspection of air carrier operations. TC indicated that its audit and inspection program would allow managers to direct audits to the areas of greatest need, in accordance with the principles of risk management. Under the new policy, no aviation company would operate without an inspection for a

* The Department of Transport improve procedures for the follow-up of any outstanding items from the audit of a company's operations.
CASB 88-31

The Department of Transport meet the frequency requirements of TP3783E for audits of operators of aircraft with restricted Aircraft Type Approvals.
CASB 90-49

period greater than 12 months, nor without an audit for a period longer than 36 months. Depending on the results of inspections and other indicators, managers would schedule audits to the frequency, depth, and scope required to ensure compliance with safety regulations. In addition, TC is developing a National Aviation Company Information System (NACIS), which TC believes will effectively increase audit resources by relieving inspectors of routine audit administrative tasks.

The TSB will continue to follow TC's system of audit, inspection and surveillance with interest.

4.1.3 *Directional Stability*

During the investigation, comments from some experienced DHC-2 pilots regarding the handling characteristics of the aircraft with certain float/fin combinations left some doubt as to its stability.

However, a TC flight test in August 1990 confirmed that the directional stability of the aircraft with Edo 4930 floats and Supplemental Type Certificate (STC) approved tip fins satisfied the requirements of BCAR Section D and CAR 03 dated 1949.

Subsequent to an accident in May 1989 on Meziadin Lake, British Columbia, it was discovered that a DHC-2 with a non-approved float/fin combination (Edo Wb-5030 floats and Kenmore Air Harbor finlets) may have encountered control difficulties.

Both of these accidents indicate that owners and operators may be unaware of the possible decrease in directional stability that may accompany non-approved combinations of floats/fins. Therefore, an Aviation Safety Advisory was sent to TC suggesting that the DHC-2 community be reminded that only approved combinations of floats and auxiliary fin/finlets are to be installed, and that TC place increased emphasis on this during inspections.

4.2 *Action Required*

4.2.1 *Shoulder Harness*

Only one occupant of the aircraft died as a direct result of injuries caused by the impact; however, all of the occupants received incapacitating head injuries. Subsequently, three occupants drowned, and two died of anoxia and inhalation of superheated gas. The use of shoulder harnesses may have prevented the head injuries and, thus, provided a chance to escape from the semi-submerged aircraft. The aircraft was not equipped with shoulder harnesses, nor was it required to be by regulation.

As a result of similar accidents, the CASB conducted a study on the influence of shoulder harnesses (CASB 87-SP0002). The results showed that significant reductions in deaths and injuries could be achieved by using shoulder harnesses. The study also concluded that the occupants of small aircraft, including the pilots, were at greater risk of injury than the occupants of large aircraft. Because of the responsibility of the pilots of small aircraft to avoid injury and, thus, be available to assist their passengers in the event of an accident, it was recommended that:

> The Department of Transport require the installation of shoulder harnesses, where practicable, in the flight crew seats of all small commercial aircraft, regardless of their date of manufacture.

CASB 87-58

In response, TC stated an intention to amend Aeronautical Navigation Order (ANO) Series II, No. 2 (the Aircraft Seats, Safety Belts and Safety Harnesses Order); however, notwithstanding this plan, the original regulation, which was proclaimed in 1966, has remained in force in Canada unchanged except for two minor amendments.

The corresponding US rules have been updated. In 1977, the FAA required that the front seats of all small aircraft certified or manufactured after 1978 be equipped with shoulder harnesses. In 1985, this requirement was extended to include all seats of small aircraft manufactured after 12 December 1986, and a companion amendment required that the shoulder harness be worn during take-off and landing. It is understood that the FAA is now considering additional rule-making regarding restraint systems.

Effective December 1984, structural provisions for shoulder harnesses have been built into all small aircraft made by members of the General Aviation Manufacturers' Association. Although this is an American organization, its members build many of the aircraft used in Canada.

Although the Federal Regulatory Plan for 1990 indicated TC's intent to introduce legislation requiring shoulder harnesses for flight crew and flight attendant seats, this has not been accomplished and is not in the Federal Regulatory Plan for 1991. In view of the continuing number of fatalities caused by the absence or non-use of shoulder harnesses in Canadian small aircraft, the TSB recommends that:

> The Department of Transport expedite legislation to require the use of a seat-belt and shoulder harness during take-off and landing of small, commercial fixed-wing aircraft.

A92-01

4.2.2 *Marking of Aircraft Exits*

Existing regulations require that each passenger position be provided with written instructions on emergency evacuation procedures, including the location and operation of emergency exits; however, this information and even briefings by crews have been shown to be ineffective in many cases. Therefore, the marking of exits, including their method of opening, is a sensible precaution. Present regulations require that emergency exits in transport category aircraft, including their means of opening, be clearly marked. The DHC-2 aircraft is exempt because it was initially manufactured well before the existence of this rule.

Escape from float-equipped DHC-2 aircraft after an accident on water has resulted in previous safety action. In October 1987, an Aviation Safety Advisory suggested that TC review the design of the door opening mechanism to ensure that egress was not hampered by difficulties in reaching and operating the door opening mechanism under conditions of stress. In August 1988, the de Havilland Company issued a service bulletin that urged operators of the DHC-2 to ensure that exits were marked clearly and provided information on how to mark them. Because the implementation of this safety bulletin was optional, an Aviation Safety Advisory to TC in September 1988 suggested that it be made mandatory by adopting it as an Airworthiness Directive. In response to these Advisories, TC issued a Service Difficulty

Alert (SDA) in March 1989 that highlighted the hazard of unclear exit markings and urged owners to implement the safety bulletin and to brief passengers on emergency egress before flight. This SDA was not mandatory, and the investigation of this accident revealed that the exits were not clearly marked in spite of the SDA.

In this accident, the escape of the occupants was precluded by their injuries; however, because many factors (such as age, panic, injury, etc.) influence post-accident survival, the impact of the lack of exit markings is difficult to assess. Nevertheless, Canadian aviation statistics show that from 1980 to 1989, there were 78 DHC-2 accidents on water involving 24 fatalities and 10 serious injuries, and that over 300 DHC-2 aircraft are still registered in Canada.

Kits for marking the exits are available for about $20 each. In view of this low cost, the need for clear exit markings that is reflected in current regulations, the accident record, and the significant number of DHC-2 aircraft still in service, it should be mandatory to maintain the exit markings in a legible condition. Regardless of the method chosen, it is recommended that:

> The Department of Transport require that the exits of the DHC-2 aircraft be marked clearly.

A92-02

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson, John W. Stants, and members Gerald E. Bennett, Zita Brunet, Wilfred R. DuPont and Hugh MacNeil, has authorized the release of this report.

Appendix A – List of Laboratory Reports

The following laboratory reports were completed:

- LP 123/90 – Material Composition – Vertical Stabilizer Fin;
- LP 141/89 – Analysis of Landing Gear and Wing Strut Fittings;
- LP 154/89 – ELT Analysis;
- LP 155/89 – Instrument Analysis;
- LP 156/89 – Seat-belt Fittings Analysis;
- LP 160/89 – Exhaust Stack Analysis;
- LP 164/89 – Aerial Photogrammetry Analysis; and
- LP 181/89 – Aerodynamic Analysis;

These reports are available on request from the Transportation Safety Board of Canada.

Appendix B – Glossary

AD	airworthiness directive
AES	Atmospheric Environment Service
AME	aircraft maintenance engineer
ANO	Aeronautical Navigation Order
asl	above sea level
ATA	Aircraft Type Approval
BCAR	British Civil Aviation Regulations
CAR	Civil Aviation Regulations
CASB	Canadian Aviation Safety Board
C of G	centre of gravity
CVR	cockpit voice recorder
ELT	emergency locator transmitter
FAA	Federal Aviation Administration
FDR	flight data recorder
hr	hour(s)
IAS	indicated airspeed
lb	pound(s)
MDT	mountain daylight time
mph	miles per hour
N	north
NACIS	National Aviation Company Information System
nm	nautical mile(s)
psi	pounds per square inch
STC	Supplemental Type Certificate
TC	Transport Canada
TSB	Transportation Safety Board of Canada
UTC	Coordinated Universal Time
W	west
°	degree(s)
′	minute(s)
″	second(s)
Z	Zulu time