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

AVIATION INVESTIGATION REPORT
A08O0035

RUNWAY OVERRUN

WESTJET AIRLINES
BOEING 737-700, C-GLWS
OTTAWA, ONTARIO
17 FEBRUARY 2008

Canada

Aviation Investigation Report

Runway Overrun

WestJet Airlines
Boeing 737-700, C-GLWS
Ottawa, Ontario
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Report Number A08O0035

Summary

WestJet flight 846, a Boeing 737-700 (registration C-GLWS, serial number 32581), was carrying 86 passengers and 6 crew members on a scheduled flight from Calgary, Alberta, to Ottawa, Ontario. The aircraft had been cleared for an instrument landing system approach to Runway 07 at Ottawa's MacDonald Cartier International Airport. The crew was advised of a considerable tailwind on approach, but that this tailwind decreased to nil by touchdown. Braking action was variously reported as poor and fair. At 2258 eastern standard time, the aircraft touched down but was unable to stop before the end of the runway. The aircraft came to rest approximately 200 feet off the departure end of Runway 07. There were no injuries to the passengers or crew and there was no damage to the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

Sequence of Events

At approximately 1 hour and 20 minutes prior to departure, the duty dispatcher completed the preliminary flight release for WestJet flight 846 (WJA 846). The aircraft had one thrust reverser inoperative; however, in accordance with WestJet MEL 78-1-1 [1],it was releasable for flight. The dispatcher determined that the forecasted weather in Ottawa would require a precision approach. This meant using Runway 07. At the time of flight planning, the Canadian runway friction index (CRFI) in Ottawa was .28 and there were reports of freezing rain and a calculated crosswind of 16 knots. The flight planned alternate airport was Windsor, Ontario, and 2000 pounds of additional fuel had been loaded as a contingency for possible arrival delays.

The crew was paired for several flights on the day of occurrence. They reported for duty at the Vancouver International Airport at approximately 1000 [2] for an early morning departure. Following the first three flights, they had a three-hour layover in Calgary, Alberta, before departing on the occurrence flight. The first officer was the first crew member to report to the departure gate in Calgary and was informed that company dispatch wanted the crew to call before boarding the aircraft. The first officer contacted dispatch and discussed the aircraft MEL status, alternate airport selection, additional fuel carriage and potential runway contamination and crosswind limitations at Ottawa.

The first officer was the pilot flying (PF) for the flight to Ottawa and the captain was the pilot not flying (PNF). The captain provided coaching during the approach and landing with respect to descent profile, speed management, and configuration changes.

Prior to descent from the en route altitude of FL 390 [3], the crew listened to automatic terminal information service (ATIS) information Echo and confirmed Runway 14 (10 000 feet) was in use. The crew briefed for the approach to Runway 14 and set up the cockpit instruments accordingly. On descent to Ottawa, WJA 846 was advised of a runway change from Runway 14 to Runway 07 and that the ATIS was now Foxtrot. The crew briefed for the instrument landing system (ILS) approach to Runway 07 via the Meech Five Arrival and set up the cockpit instruments accordingly (see Appendix B – Meech Five Arrival and Appendix C – Instrument Landing System (ILS) Approach, Runway 07, Ottawa.

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1 Minimum equipment list item for thrust reverser inoperative

2 All times are eastern standard time (Coordinated Universal Time minus five hours)

3 Flight level 390; 39 000 feet above mean sea level

At the top of descent, the crew used the *WestJet Flight Operations Manual* (FOM) to calculate the required landing distance for Runway 14, landing distance available (LDA) 10 000 feet. They determined that they needed 6000 feet. Although Runway 07 (LDA 8000 feet) is 2000 feet shorter than Runway 14, the crew felt they still had a sufficient landing distance buffer using the same parameters. They planned a flaps 30, autobrake 3 landing with a landing reference speed (Vref) [4] of 130 knots. They did not intend to use reverse on landing due to runway conditions and the effect of asymmetry due to the number 2 thrust reverser being inoperative.

At approximately 2245, following several altitude step-down sequences, WJA 846 was handed off to the Ottawa Terminal controllers of the Montreal Area Control Centre (ACC) and cleared to the MODON [5] intersection to maintain 6000 feet above sea level (asl). The flight was advised that the current ATIS information was now Golf. A review of the aircraft's ACARS [6] (aircraft communication addressing and reporting system) indicated that the crew made requests for ATIS information updates shortly after being advised of changes in ATIS information.

At 2246, an Embraer 170 landed on Runway 07. The crew reported to Ottawa Tower that the braking action was poor and there was a strong tailwind on approach. They also indicated that the tailwind decreased to nil by touchdown and there was no wind shear. Ottawa Tower advised Ottawa Terminal of the wind information but omitted the braking action information. At 2247, Ottawa Terminal advised WJA 846 of the wind information. The crew discussed the need to configure the aircraft for the approach early due to the wind conditions. At 2248, the speed brakes were deployed to reduce the airspeed below 250 knots before descending below 10 000 feet asl. At 2250, the aircraft had descended through 10 000 feet asl and the crew completed the descent-approach checklist. The autobrake 3 setting was confirmed.

Calculation for determining the rate of descent for a 3° glide path is five times the groundspeed [7]. For example, a groundspeed of 120 knots would require a descent rate of 600 feet per minute. An increase in groundspeed to 180 knots would require a descent rate of 900 feet per minute. The greater the groundspeed, the greater the rate of descent required to maintain the glide path. An increase in groundspeed also reduces the amount of time the crew has to correct the approach profile before arriving at the runway threshold.

At approximately 2250, the aircraft was further cleared to 4000 feet asl and received clearance for the ILS approach to Runway 07 via VISOL [8]. For the next five minutes, the crew focused on energy management of the aircraft, targeting to cross VISOL at a speed of 170 to 175 knots. During this time, the thrust levers were at idle, the speed brakes were deployed, and flaps 5 had

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4 Vref is the minimum approach speed based on aircraft weight and configuration.

5 Modon is the downwind termination waypoint on the Meech Five arrival.

6 ACARS is a datalink system that provides in-flight information exchanges with company operations.

7 Transport Canada *Instrument Procedures Manual* (TP 2076)

8 Intermediate fix for ILS Runway 07

been selected. At 2254:40, approaching VISOL, the turn for final approach was initiated. At that time, the aircraft was at an altitude of 4300 feet asl with an airspeed of 169 knots. During the turn, the speed brakes were stowed, the landing gear was placed in the down position, and flaps 15 were selected. At 2255:12, WJA 846 was instructed to contact Ottawa Tower. A minute later, the crew noted a tailwind component of 74 knots. At 2255:42, the crew noted the glide slope and localizer indications on the primary flight display (PFD) were active and began the landing checklist; the speed brakes were armed as part of this checklist. The crew gained visual contact with the runway at the time of glide slope interception.

At 2256:32, the glide path was intercepted, and in accordance with company standard operating procedures (SOPs), flaps 30 should have been selected. However, the aircraft speed was above the flaps 30 selection speed and the speed brakes were deployed to reduce the airspeed. The crew had not yet contacted Ottawa Tower and at 2257:06, WJA 846 was asked by the tower if they were on frequency. A 20-second communication exchange ensued during which several activities were concurrently happening in the cockpit. WJA 846 advised that they had a strong tailwind and might have to initiate a go-around. At approximately 1500 feet above ground level (agl), the crew disconnected the autopilot in order to level off and reduce airspeed for the flaps 30 selection. The speed brakes were then stowed, but not re-armed for landing and flaps 30 was selected. The airspeed on final approach varied between 145 and 177 knots (see Appendix D – Flight Data Recorder plot, last 10 nautical miles).

At 2257:14 the tower controller cleared WJA 846 to land and mentioned that the tailwind was reported to decrease by touchdown. The controller added that surface winds were 130° magnetic at 6 knots. At 2257:26, 46 seconds prior to touchdown, WJA 846 was cleared for landing a second time and advised that braking action had been variously reported as fair and poor. The crew did not acknowledge this advisory and did not recall hearing it. There is no requirement to specifically acknowledge information received about braking action.

Immediately following the flaps 30 selection and the conversation with tower, the crew momentarily considered the requirement to conduct a missed approach. The decision was deferred even though the aircraft was approaching the 1000-foot above airfield elevation point. At the 1000-foot point, the aircraft flight parameters were as follows: in final landing configuration, thrust levers idle, airspeed 145 knots, and above glide path. Except for the momentary level-off, the thrust levers were at idle for the entire final approach. The aircraft was above glide path during the final approach except for three brief moments: at three nautical miles (nm), at ¾ nm from the threshold, and at threshold crossing (at 50 feet agl). The rate of descent was in excess of 1000 feet per minute for most of the final approach (see Table 1).

Altitude (AFE)	Airspeed*	Estimated Descent rate	Glide path***
1000 feet	145 knots	1394 fpm**	2 ½ dots above
900 feet	152 knots	1733 fpm	2 ½ dots above
800 feet	151 knots	1443 fpm	2 ¼ dots above
700 feet	157 knots	1500 fpm	2 dots above
600 feet	157 knots	1731 fpm	1 ¾ dots above
500 feet	154 knots	1770 fpm	1 ¼ dots above
400 feet	161 knots	1632 fpm	½ dot above
300 feet	149 knots	515 fpm	¾ dot above
200 feet	150 knots	1124 fpm	1 ¼ dot above
100 feet	150 knots	1094 fpm	¾ dot above
* Vref was 130 knots ** feet per minute *** as indicated on the PFD			

Table 1. Final approach parameters.

The landing flare was initiated at approximately 50 feet agl and 149 knots (Vref + 19). At 2258, the aircraft touched down (both main wheels on the ground) approximately 2300 feet past the threshold. The airspeed at touch down was 140 knots, Vref + 10 knots. The radio altitude indicated a significant decrease in descent rate (float) before touchdown. Although autobrake 3 was selected, manual braking was applied one second after touchdown. The captain initially assisted the first officer with the braking and then took control of the aircraft. Full manual braking was applied and held until the aircraft came to rest. The number 1 engine reverser deployment was activated approximately 1.5 seconds after initial right wheel [9] contact and full deployment occurred approximately 4.5 seconds after initial right wheel contact. Maximum reverse was commanded 11 seconds after initial right wheel contact and remained at maximum until the aircraft came to rest. Because the speed brake was not armed, spoiler deployment was

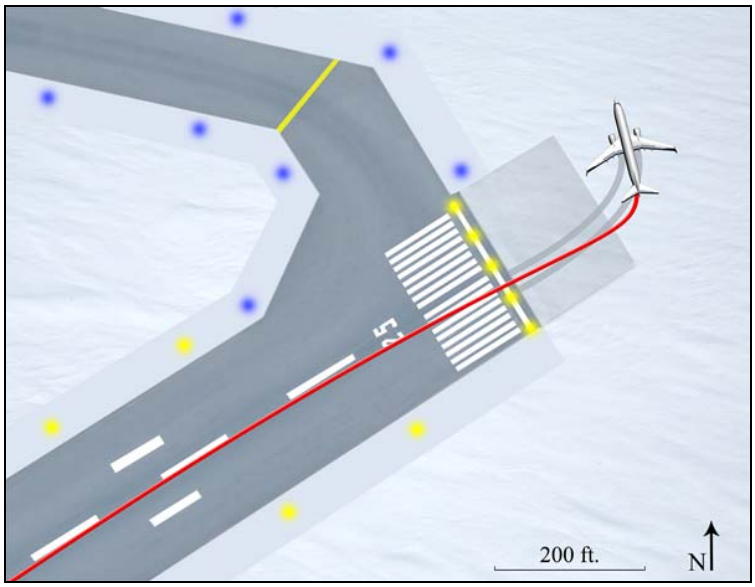

Figure 1. Site diagram

[9] If the speed brake is armed, compression of the right main strut enables deployment of the ground spoilers.

automatically initiated with application of reverser. The ground spoilers were fully deployed approximately two seconds after initial right wheel contact. The aircraft departed the end of the runway at 40 knots and overran the end by 215 feet (see Figure 1). There was a depth of approximately two feet of snow in the overrun area.

The tower controller activated the crash alarm at 2259. Shortly thereafter, WJA 846 requested the emergency vehicles and advised the tower that they were off the end of Runway 07. Red 1 [10] contacted Ottawa Tower at 2259:50 and was advised of the type and location of the incident. The tower controller cleared the response vehicle onto the runway. Although airport grid maps were available in both the tower and ground vehicles, the maps were not used to provide coordinates for the aircraft's position. *Canadian Aviation Regulation* (CAR) 302.206(4) requires grid maps to be available but does not mandate their use.

Shortly after arrival of the emergency vehicles, WJA 846 was switched to a discrete frequency to coordinate response activity. The captain determined that an emergency evacuation was not required and the passengers and crew waited while air stairs were positioned for deplaning. The passengers were taken to the terminal by bus.

Crew Information

The captain was certified and qualified for the flight in accordance with existing regulations. The captain had 15 000 hours of total flying time; 2750 hours were on the Boeing 737, of which 450 hours were as pilot-in-command. The captain had been off duty from the 11th to the 16th of February 2008.

The first officer was certified and qualified for the flight in accordance with existing regulations. The first officer had 8000 hours of total flying time; 100 hours were on the Boeing 737. He had recently joined the company and had completed his initial Boeing 737 pilot proficiency check (PPC) on 08 December 2007. His line indoctrination was completed on 01 January 2008. He had last flown on 12 February 2008 and was paired with the captain starting the morning of the occurrence.

The crew had been on duty for approximately 13 hours at the time of the occurrence. This included a three-hour layover in Calgary.

Aircraft

The number 2 engine thrust reverser was identified as unserviceable on 16 February 2008. Maintenance personnel deferred the repair in accordance with the MEL and the number 2 engine thrust reverser handle was locked-out. Post-occurrence maintenance activity on the aircraft did not find any anomalies with respect to the engines, braking system, or flight controls.

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[10] Red 1 was the first responding fire truck from the airfield fire hall.

The cockpit voice recorder (CVR) and flight data recorder (FDR) were recovered and provided useful information to the investigation.

Airport Information

Ottawa International Airport has three runways: Runway 07/25 is 8000 feet long and 200 feet wide with an asphalt surface; Runway 14/32 is 10 000 feet long and 200 feet wide with an asphalt surface; and Runway 04/22 is 3300 feet long and 75 feet wide with an asphalt surface (See Appendix A – Ottawa Airport Diagram). Runway 14 is served by a VOR [11] approach (minimum descent altitude (MDA) of 533 agl). Runway 07 is served by an ILS (decision height 200 feet agl). The ILS approach to Runway 07 has a 3° glide path and localizer heading of 071°magnetic. The ground point intercept for the glide path is 1068 feet from the threshold. The overrun area for Runway 07 has a 200-foot wide paved section that extends 150 feet past the end of the runway. Beyond that, a grassed area extends approximately 750 feet.

The Ottawa International Airport has two TES Instruments MK3 decelerometers used for measuring CRFI. Both are sent to the manufacturer for calibration and certification on an annual basis. The last certification was in August 2007. All staff responsible for reporting runway surface conditions and CRFIs completed a winter aircraft movement surface condition reporting course on 30 April 2004. A pre-season review of winter operations occurs prior to the start of each winter.

To determine the runway friction index, decelerometer readings are taken along both sides of the centreline at 1000-foot intervals. For Runway 07-25, 14 readings are taken and the average of these readings is used to produce the CRFI. A calibration check of the decelerometer equipment was not conducted following the occurrence.

Weather data

The weather in Ottawa on 17 February 2008 was changing rapidly through the course of the day. Several forecast amendments were issued. At the time that dispatch was planning the flight, the amended terminal area forecast (TAF) for Ottawa issued on 17 February at 1714 with a validity period of 1700 on the 17th until 0900 on the 18th was as follows:

> Wind 100° True (T) at 10 knots, visibility 6 statute miles (sm) in light snow, rain and mist, scattered cloud at 500 feet agl, overcast cloud at 1500 feet agl; temporarily between 1700 and 1900 visibility 3 sm in light freezing rain and mist, broken cloud at 500 feet agl, and overcast cloud at 1500 feet agl. From 1900, wind 110°T at 10 gusting 20 knots, visibility 2 sm in light rain and mist, overcast 600 feet agl; temporarily between 1900 and 0600, visibility ½ sm in light rain and mist with vertical visibility 200 feet.

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[11] Very high frequency omnidirectional range

The TAF at the time of arrival in Ottawa, issued on 17 February at 2143 with a validity period of 2200 on the 17th until 1900 on the 18th was as follows:

> Wind 120°T at 7 knots, visibility 3 sm in light rain and mist, overcast cloud at 900 feet agl; temporarily between 2200 and 2400, visibility greater than 6 sm, no significant weather, scattered cloud at 900 feet agl, overcast cloud at 5000 feet agl.

The actual weather conditions in Ottawa on 17 February reflected the changing conditions with many special reports (SPECIs) issued in addition to the hourly reports (METARs). The following is a list of actual weather reports issued in the hours leading up to the occurrence:

2154 SPECI – Wind 110°T at 6 knots, visibility 3 sm in mist, overcast cloud at 800 feet agl, temperature 1°C, remarks stratus fractus 8 oktas [12]

2200 METAR – Wind 110°T at 5 knots, visibility 3 sm in mist, overcast cloud at 800 feet agl, temperature 1°C, dew point 1°C, altimeter 29.49 inches of mercury (in of HG), remarks stratus fractus 8 oktas, sea level pressure 993

2234 SPECI - Wind 100°T at 6 knots, visibility 2 sm in mist, broken cloud at 1100 feet agl, overcast cloud at 3000 feet agl, temperature 1°C, remarks fog 2 oktas, stratus fractus 4 oktas, stratocumulus 2 oktas

2300 METAR - Wind 130°T at 7 knots, visibility 2 sm in mist, scattered cloud at 1100 feet agl, overcast cloud at 3000 feet agl, temperature 1°C, dew point 1°C, altimeter setting 29.45 in of Hg, remarks fog 2 oktas, stratocumulus 2 oktas, stratocumulus 4 oktas, moon visible, sea level pressure 979

Runway Surface Condition

At approximately 1300, due to the forecasted freezing precipitation, the airport authority had pre-treated the runways with potassium acetate [13]. The freezing rain started falling around 1400 and freezing rain and rain continued falling until 1900. Sodium formate [14] was applied to both runways (07/25 and 14/32) at around 1700. Runway exits were continuously treated with sodium formate and sand, especially at taxiway foxtrot. Runway 07 had just been sanded from taxiway foxtrot to the runway end prior to the landing of WJA 846. In the hours before the occurrence, there were airfield condition reports submitted at 1559, 1719, 1743, 1820, 1935, 2127, and 2250.

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12 Okta – Cloud layer opacity in eighths of sky obscured.

13 Non-corrosive de-icing chemical applied to runway surfaces.

14 Non-corrosive de-icing chemical applied to runway surfaces.

The airfield runway surface condition report for Runway 14 issued at 2127 was as follows:

- 120-foot centre cleared;
- 60% bare and wet, 40% ice, patches of ice;
- sand applied (width of 75 feet);
- chemicals applied (width of 100 feet);
- remaining width 40% compact snow, 60%ice;
- friction data – Runway 14 CRFI .35 at 2127; and
- Air temperature of 1°C.

The airfield runway surface condition report for Runway 07 issued at 2127 was as follows:

- 120-foot centre cleared;
- 60% bare and wet, 40% ice, patches of ice;
- sand applied (width of 75 feet);
- chemicals applied (width of 100 feet);
- remaining width 60% compact snow, 40%ice;
- friction data – Runway 07 CRFI .34 at 2118; and
- air temperature of 1°C.

The airfield runway surface condition report for Runway 07 issued at 2250 (8 minutes prior to touchdown) was as follows:

- 120-foot centre cleared;
- 60% bare and wet, 40% ice;
- sand and chemical present (applied at 2243);
- remaining width – 60% compact snow, 40% ice;
- friction data – CRFI .35 at 2244; and
- air temperature of 1°C.

Runway 07 was closed by NOTAM (notice to airmen) following the occurrence and no further runway surface condition reports were generated. The next runway surface condition report issued was for Runway 14 (at 0040) and was as follows: 120 feet cleared, 70% bare and wet, 30% ice, sand and chemical present, remaining width compact snow 40%, ice 60%. The temperature and CRFI had been trending upward in the hours prior to the WJA 846 landing.

Automatic Terminal Information Service

The ATIS provides a continuous loop recording of the current weather and runway conditions at the airport. Ottawa International Airport information Echo was issued at 2159. It included the special weather issued at 2154 as well as the runway surface condition reports for Runway 07 and Runway 14 issued at 2127. The active runway was Runway 14; the instrument approach was VOR Runway 14.

Ottawa International Airport information Foxtrot was issued at 2218. It included the weather issued at 2200 as well as the runway surface condition reports for Runway 07 and Runway 14. The active runway was now Runway 07; the instrument approach was ILS Runway 07.

Ottawa International Airport information Golf was issued at 2237. It included the special weather issued at 2234 as well as the runway surface condition reports for Runway 07 and Runway 14 (issued as of 2127). The active runway was still Runway 07; the instrument approach was ILS Runway 07.

Air Traffic Services

Air traffic control (ATC) procedures for all instrument flight rules (IFR) and visual flight rules (VFR) flights operating in the vicinity of Ottawa International Airport are defined in an arrangement between the Ottawa Control Tower and the Montreal ACC. The configuration of the runway(s) to be used at Ottawa is a joint decision between the Ottawa Tower and Ottawa Terminal controllers of the Montreal ACC and depends on the weather conditions. The arrangement states that, in visual meteorological conditions (VMC), the Ottawa Tower shall determine the runway in use and, in instrument meteorological conditions (IMC), the terminal, in consultation with Ottawa Tower, shall determine the runway in use.

When the 2154 SPECI weather report was issued, personnel at the Montreal ACC misinterpreted the 800-foot overcast condition as cloud height asl instead of agl. This would give a cloud ceiling of 426 feet agl (800 foot asl overcast minus the airfield elevation of 374 feet). This figure would have been below the MDA for the VOR approach to Runway 14 (533 feet agl). Since IMC prevailed, runway selection was the purview of the Montreal ACC. Following a discussion with the Ottawa Tower, a change to Runway 07 was made as it is serviced by an ILS approach with minimums of 200 feet agl. The surface wind direction was varying between 100°T and 140°T and had been favouring Runway 14.

When broadcasting the braking action report to an Embraer 170 and to WJA 846, the controller did not include the type of aircraft reporting or the time of the report. This was contrary to the format described in ATC MANOPS. [15]

The Ottawa Tower is designated to provide air traffic services (ATS) in either official language. The ATIS information is broadcast in English and French on separate frequencies. The ATC facility is equipped with a computer software program called Digital ATIS that provides a text to speech capability and the automatic gathering of some of the information that is to be broadcast. Separate entries are made for the French and English versions, and the two versions have to be verified separately. Some of the translation is done automatically by the program and some has to be done manually by a controller. The airfield condition report, as received from the airport operator, is manually entered and requires some manual translation into the other official language. The syntax is often very particular. Errors or words the program does not recognize, because there is no text to speech data, are not apparent to the controller until the verification process (listening to the message). If an error is detected, the program will stop the verification at that point and require correction. This can be time consuming and takes the controller's attention away from other tasks. When a subsequent ATIS message is prepared and no change to previously-entered information is received, it does not have to be re-entered.

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15 ATC MANOPS is the acronym for the NAV CANADA *Air Traffic Control Manual of Operations.*

A review of the ATIS messages Charlie through Golf on the night of the incident indicated that the French and English versions differed. The French version did not contain the same level of detail on the runway surface condition of Runways 07 and 14 as was included in the English version. Missing from the French version on the five ATIS messages prior to this incident was the fact that ice patches were present on Runway 07 and that sand had been applied. For Runway 14, the French ATIS messages did not indicate that the runway had been sanded. The correction to the airfield condition for both runways was made after the incident, with ATIS message Hotel.

Operator SOP Information

The WestJet FOM, section 4, page 117 describes the criteria for a stabilized approach as follows:

> The approach shall be stabilized no later than 1000 feet above field elevation (AFE). Boeing describes a stabilized approach as follows:
>
> - aircraft in the final landing configuration
> - power setting appropriate for aircraft configuration
> - airspeed no greater than target + 20 and trending towards target
> - on glide slope or assumed 3° glide slope
>
> **Note**: Descent rates above 1000 feet per minute should be avoided. If the approach is not stabilized at 1000 AFE or becomes unstable below 1000 feet, a go-around must be executed.

The FOM, section 4, page 85 describes the autobrake system use. There are four autobrake settings: 1, 2, 3, and Max. Setting 2 or 3 should be used when moderate deceleration rates are required for wet and/or slippery runways, when landing rollout distance is limited, anytime a reverser is inoperative, for single-engine landings, and for any landing requiring higher than normal speeds. Max setting should be used when maximum deceleration rates are required for minimum stopping distance. The deceleration rate when using the Max setting is less than that produced by full manual braking.

The FOM has landing distance charts for wet or contaminated runways using flap settings of 15, 30, and 40. The crew chooses a flap setting based on such variables as runway length, runway slope, wind, runway surface condition reports, CRFI, and braking action reports.

The FOM, section 4, page 91, describes the typical ILS pattern. Flaps 5 is selected on the procedure turn outbound or intercept to final. On final approach with an indication that the glide slope is alive [16], flaps 15 are selected, the landing gear is lowered, and the landing checklist is executed. On intercept of the glide slope, landing flaps (either 30 or 40 as decided by the crew) is selected.

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[16] The glide slope or localizer is alive when it begins to become active on the PFD.

Aircraft Performance Calculations

The FOM contains a section for calculating landing distance on a dry runway as well as a section for calculating landing distance on a wet or contaminated runway. The section for wet or contaminated runway is further divided into subsections of CRFI information available and not available. If CRFI information is available, the crew adds an adjustment to the dry runway distance based on the Transport Canada CRFI table for recommended landing distances. The CRFI landing distances are based on a 95% level of confidence. A 95% level of confidence means that in more than 19 landings out of 20, the stated distance will be conservative for properly executed landings with all systems serviceable on runway surfaces with the reported CRFI.

The crew had calculated 6000 feet [17] as the distance required for a landing on Runway 14. This was predicated on a planned landing weight of 122 513 pounds, flaps 30, no reversers, auto speed brakes, CRFI of .35 (from ATIS), Vref of 130 knots, and wind 120°T at 6 knots (from the 2143 TAF). They determined that these numbers were also suitable for a landing onto Runway 07.

Subsequently, TSB investigators calculated the landing distance required to be approximately 6230 feet to land on Runway 07. [18] This was predicated on a planned landing weight of 122 513 pounds, flaps 30, no reversers, CRFI of .34 (from ATIS), Vref of 130 knots, and wind 130° magnetic at 6 knots (tower reported winds), and included an additional 170 feet for manual speed brake deployment because the speed brakes were not armed for landing.

The distances in the FOM performance charts are actual distances (unfactored [19]) from 50 feet above runway threshold to stop and include 1000 feet of air distance prior to touchdown. The numbers are predicated on a landing made from 50 feet at Vref. Information from the aircraft manufacturer indicates that the performance charts also assume that the touchdown speed is approximately equal to the threshold crossing speed. Although the actual aircraft threshold crossing speed was 149 knots (Vref + 19), the extended float time makes this value unsuitable for FOM performance chart calculations.

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17 Using the *WestJet Flight Operations Manual*, Boeing 737NG, sections 10B-24K, Revision 012 dated 30 October 2006. This included an adjustment for the reported CRFI using the Transport Canada CRFI table for recommended landing distances (no discing/reverse thrust).

18 Using *WestJet Flight Operations Manual*, Boeing 737NG, sections 10B-24K, Revision 012 dated 30 October 2006. This included an adjustment for the reported CRFI.

19 The CAR 705.60 (1) dispatch limitation factor of 1.67 times the chart number has not been applied.

Therefore, for calculation purposes, it was assumed by the TSB that the speed at threshold was approximately equal to the touchdown speed. The aircraft speed at touchdown was 140 knots (Vref + 10). Applying a Vref adjustment for the extra 10 knots results in a required landing distance of approximately 6800 feet. After removing 1000 feet for the air time, this equates to a ground roll of approximately 5800 feet. Due to the conservative nature of the CRFI tables mentioned above, this ground roll distance will be longer than the actual ground roll distance of the aircraft, depending on conditions. TSB calculations using FDR data show that the ground roll distance was approximately 6200 feet. This ground roll estimation is the distance the aircraft would have travelled if it had remained on a surface with the same aircraft braking coefficient.

The FOM states that performance charts for CRFI restricted runways are predicated on an autobrake setting of Max. The FOM does not contain a definition for a CRFI restricted runway. During the investigation, WestJet crews were asked to define a CRFI restricted runway; there was no consistent response.

If the speed brakes are armed for landing, the ground spoilers will deploy 0.1 to 0.3 seconds following the activation of the air/ground switch. This is due to an internal processing delay. If the speed brakes are not armed at landing when the reverse thrust is selected, the extension of the ground spoilers is almost instantaneous. It takes approximately one second for the spoiler panels to reach full extension.

Boeing Performance Calculations

In order to better understand the factors involved during the ground roll phase of the landing, the aircraft manufacturer, Boeing Commercial Aircraft (Boeing), was requested to perform the following two tasks in support of the investigation:

- estimate the airplane braking coefficient at the time of the occurrence
- estimate the ground roll of the occurrence aircraft for different aircraft landing scenarios

Airplane braking coefficient is a calculated term defined as the ratio of the deceleration force from the wheel brakes relative to the normal force acting on an airplane. The airplane braking coefficient is an all-inclusive term that incorporates effects due to the runway surface, contaminants, and airplane braking systems (for example, antiskid efficiency, brake wear, tire condition, etc.). Therefore, airplane braking coefficient is not equivalent to the tire-to-ground friction coefficient that would be measured by an airport ground vehicle conducting runway surface conditions.

The airplane braking coefficient represents the runway characteristics between touchdown and the point where the airplane departed the runway. The airplane braking coefficient of the occurrence aircraft, calculated by Boeing, was approximately 0.05. This is consistent with a runway condition of "poor" (generic ice, wet ice) as indicated in the Boeing 737 *Quick Reference Handbook*. A conversion table [20] showing the relationship between airplane braking coefficient and CRFI equates airplane braking coefficient of 0.05 to a CRFI of 0.08. The reported CRFI of 0.34 equates to an airplane braking coefficient of approximately 0.16.

The ground roll analysis was done using a software application developed by Boeing called the low-speed performance system (LSPS). The program is intended to predict actual airplane performance and makes some assumptions regarding the operation of the airplane. It is assumed that the deceleration device application occurs promptly after touchdown and the reversers are cut back at a speed of 60 knots as per Boeing recommended procedures. The results did not include the air run nor was there any factor applied. Table 2 is a selection of scenarios calculated by Boeing showing the effect of varying landing speeds and surface conditions:

Touchdown Speed	Speed brakes	Number of reversers	Reverse setting	Airplane Braking Coefficient (μ)	Ground roll
130 knots [21]	Auto	1	Detent 2	0.05	6500 feet
130 knots	Auto	1	Detent 2	0.16	3293 feet
140 knots [22]	Manual	1	Detent 2	0.05	7123 feet
140 knots	Auto	1	Detent 2	0.05	7023 feet
140 knots	Auto	1	Detent 2	0.16	3642 feet

Table 2. Boeing calculations

Stabilised Approaches

The Flight Safety Foundation Approach-and-landing Accident Reduction (ALAR) Task Force studied 76 approach-and-landing accidents and serious incidents from the years 1984 to 1997 and found that unstabilised approaches were a causal factor in 66 per cent of these occurrences. [23] This article describes some of the benefits of a stabilised approach as follows: increased horizontal, vertical, airspeed, and energy condition awareness; provides more time for monitoring ATC communication and more time for monitoring and back-up by the PNF.

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20 Proceedings of the Third International Meeting on Aircraft Performance on Contaminated Runways, TP 13579, *Prediction of Aircraft Landing Distance on Winter Contaminated Runways Using the Canadian Runway Friction Index*, John B. Croll, November 2004.

21 Vref

22 WJA 846 actual landing speed

23 Flight Safety Foundation ALAR Toolkit, *Flight Safety Digest*, August-November 2000

The article further describes some of the deviations that are often involved in unstabilised approaches:

- entire approach flown at idle thrust down to touchdown;
- late extension of flaps;
- excessive flight-parameter deviation when crossing the minimum stabilisation height (i.e. excessive airspeed, excessive rate of descent, above glide slope);
- excessive flight-parameter deviation down to runway threshold;
- speed brakes remain extended on short-final approach; and
- extended flare and extended touchdown.

Human Performance Issues

At various times during a flight, such as during take-off and descent, a pilot's workload can be very high. As workload increases due to greater task difficulty or an increase in the number of tasks being undertaken, the requirement for mental processing increases. If the processing demands of a task or tasks exceed the available capacity, performance decrements result. Periods of higher-than-normal workload can lead to errors and system failures. For example, a pilot may mishear or misunderstand information that is communicated, a pilot may inadvertently shed tasks and only pay attention to those that are most salient to the task at hand, or the pilot may be distracted from primary tasks.

Analysis

The number 2 engine thrust reverser was unserviceable and the repair was deferred in accordance with the MEL. There were no aircraft-related issues that contributed to the occurrence. Both pilots had several days off prior to reporting for duty on the day of the occurrence. Although the overrun took place at the 13-hour point, the crew had a 3-hour layover prior to departing on the final leg to Ottawa. Fatigue was not considered to be a contributing factor. The analysis will therefore examine the environmental conditions at the time of occurrence, the crew actions during the approach and landing, and ATS activities.

The Approach and Landing

The crew was aware of the tailwind on approach and had discussed the need for early configuration for landing. They had selected gear down and flaps 15 earlier than called for in the FOM, on the turn to final rather than after the indication of glide path and localizer alive. On final approach, even with the thrust levers at idle, gear down, and flaps 15, the indicated airspeed did not decrease sufficiently to allow for extension of landing flaps. The crew therefore elected to deploy speed brakes, disconnect the autopilot, and level off at approximately 1500 feet agl. At 1000 feet agl, the aircraft was not on the glide path, had a descent rate in excess

of 1000 feet per minute, and the thrust levers were still at idle. The criteria for a stabilized approach were not met and a go-around should have been initiated. The increased groundspeed due to the tailwind had resulted in an energy management difficulty that was not corrected before 1000 feet AFE and continued all the way down to the landing flare.

The captain was coaching the first officer regarding energy management and approach profile. The workload associated with this coaching activity increased after the turn to final due to the 74 knot tailwind component and consequently the captain began to shed some of the PNF activities. He did not check-in on tower frequency until he was prompted and he did not hear the braking action report given on short final — indications that he was becoming task saturated. In addition, the speed brake was not re-armed when stowed. As the landing checklist had already been completed, there was no further cross-check to ensure its status. Adding to the situation was the fact that the captain was engaged in a communication with Ottawa Tower just prior to the 1000-foot limit for the stabilised approach criteria. Although the crew momentarily considered a go-around, the captain was not immediately able to assess if the approach was stabilized and deferred the go-around decision when conditions indicated otherwise. The aircraft speed, its position relative to the glide path, and the rate of descent, from 1000 feet AFE to 100 feet AFE, also indicated that the approach was not stabilised and that a go-around should have been initiated.

Although the speed brakes were not armed for landing, the ground spoilers were fully deployed approximately 2 seconds after initial right wheel contact. This was very close to the timing of auto-deployment (0.3 second processing delay + 1 second travel). Table 2 on page 14 shows that the unarmed speed brake contributed 100 feet to the ground roll. Therefore, the unarmed speed brakes contributed only marginally to the stopping distance.

The speed of the aircraft at the point of threshold crossing (Vref + 19) and the prolonged float time resulted in an increase in the landing distance required. The aircraft was approximately 2300 feet down the runway at touchdown and had only 5700 feet of runway remaining.

Aircraft Performance

Based on a CRFI of .34, FOM performance chart calculations show that approximately 5800 feet of ground roll distance was required for a landing at Vref + 10. TSB calculations using FDR data show that the ground roll distance would have been approximately 6200 feet if the airplane had remained on a surface with the same airplane braking coefficient.

The Boeing analysis shows that for a stabilised landing at Vref, using either the Boeing calculated airplane braking coefficient of 0.05 μ (CRFI ~ 0.08) or the measured CRFI of .34 (airplane braking coefficient of 0.16 μ), the ground roll distance would be 6500 feet and 3293 feet, respectively. Assuming 1000 feet of air time, this would have resulted in the aircraft remaining on the runway for either scenario.

However, the aircraft touched down at 140 knots, which was Vref + 10. The Boeing analysis shows that for a stabilised landing at Vref + 10, using either the Boeing calculated airplane braking coefficient of 0.05 μ (CRFI ~ 0.08) or the measured CRFI of .34 (airplane braking coefficient of 0.16 μ), the ground roll distance would be 7123 feet and 3642 feet, respectively.

Assuming 1000 feet of air time, this would have resulted in an overrun of 123 feet for an airplane braking coefficient of 0.05 μ (CRFI ~ 0.08). For a measured CRFI of .34 (airplane braking coefficient of 0.16 μ), the aircraft would have remained on the runway.

Not only did the aircraft land at Vref + 10, the touchdown point was estimated to be approximately 2300 feet from the threshold. Adding 2300 feet to the ground roll numbers from the previous paragraph, this would have resulted in an overrun of 1423 feet for an airplane braking coefficient of 0.05 μ (CRFI ~ 0.08). For a measured CRFI of .34 (airplane braking coefficient of 0.16 μ), the aircraft would still have remained on the runway.

The above scenarios show that for a measured CRFI of .34, the aircraft should have stayed on the runway regardless of the touchdown parameters. However, the aircraft departed the end of the runway, suggesting that the actual CRFI was less than the measured CRFI. The actual overrun was 215 feet. Even considering the deceleration effect of the snow in the overrun area, this is considerably less than the overrun of 1423 feet estimated by the Boeing analysis for an airplane braking coefficient of 0.05 μ (CRFI ~ 0.08). This would suggest that the actual aircraft braking coefficient was somewhere between the Boeing calculated value of 0.05 and the reported CRFI of .34 (airplane braking coefficient of 0.16 μ).

A CRFI reading was not taken on Runway 07 post-event. Also, a calibration of the decelerometer was not conducted post-event. Therefore, it is not possible to state with certainty what the condition of the runway surface was at the time of the landing.

What can be said, however, is that the runway was more slippery than reported and, combined with the long and fast landing, resulted in an increase to the required landing distance. This increase in the required landing distance was in excess of the remaining runway available and this resulted in the overrun.

ATC Issues

WJA 846 did not contact the Ottawa Tower when the aircraft was turning onto the final approach track as instructed by Ottawa Terminal. As a result, the time available for the Ottawa Tower controller to provide relevant information such as braking action reports was considerably reduced. The late check-in and the pronouncement by the crew of a possible missed approach may have provided enough of a distraction that the braking action report was mentioned late in the final approach phase as an addendum to the second landing clearance. Because there is no requirement to specifically acknowledge information received about braking action, the controller could not be sure that the information had been received. In addition, the braking action report did not include the aircraft type and time. This was contrary to ATC MANOPS and reduced the usefulness of the braking report as crews could not put the information into context with their own aircraft and expected landing time.

The misinterpretation of the ceiling height by ATC personnel resulted in the change from Runway 14 to Runway 07. The rationale for the change was to allow aircraft to descend below what was mistakenly believed to be a ceiling of 426 feet agl before reaching approach minimums. This resulted in the significant winds aloft being on the tail, versus abeam of the aircraft conducting approaches into Ottawa. The tailwind created energy management problems for the occurrence crew and was one of the factors that contributed to an unstabilised approach.

The digital ATIS program requires some information to be manually entered. The airfield condition report, as received from the airport operator, is manually entered, and requires some manual translation into the other official language. When a subsequent ATIS message is prepared and no change to previously-entered information is received, it does not have to be re-entered. If the information was not correctly entered initially, then the mistake may be perpetuated through subsequent ATIS messages. In this incident, the correction was not made until after the incident. Although controllers check both the French and English versions of the ATIS message before it is broadcast, an error may not be readily apparent if it is not compared simultaneously with the written version. Errors in automatic ATIS generation could result in a situation where flight crews are making in-flight decisions based on incorrect or missing information.

Although airport grid maps were available in both the tower and ground vehicles, the maps were neither required nor used to provide coordinates for the aircraft's position. This could result in confusion as to aircraft position and delays in rescue response in other occurrences.

WestJet Flight Operations Manual (FOM)

The WestJet FOM description of autobrake setting criteria is somewhat misleading in that the use of autobrake setting 3 would seem reasonable for the occurrence flight given the inoperative reverser and runway conditions. However, when calculating the landing performance data, the chart indicates autobrake Max should be used for CRFI restricted runways. This term is not described in the FOM and it is possible crews could misinterpret which setting to use.

The following reports were produced by the TSB Engineering Laboratory:

LP 027/2008 – FDR Download
LP 042/2008 – Review of Maintenance Documents

These reports are available from the Transportation Safety Board upon request.

Findings as to Causes and Contributing Factors

1. The crew of WJA 846 had difficulty with aircraft energy management due to the strong tailwind for the revised runway, and this resulted in an unstabilised approach.

2. The captain became task saturated while coaching the first officer during the final stages of the approach. He did not make an assessment that the approach was unstabilised at either the 1000-feet above field elevation or, subsequent to that point, when conditions indicated otherwise.

3. The runway was more slippery than reported and, combined with the long and fast landing, resulted in an increase to the required landing distance. This increase in the required landing distance was in excess of the remaining runway available and this resulted in the overrun.

4. The speed brakes were not armed and their late activation added marginally to the stopping distance.

Findings as to Risk

1. Contrary to the NAV CANADA *Air Traffic Control Manual of Operations* (ATC MANOPS), the braking action report did not include the aircraft type and time. This reduces the usefulness of a braking report as crews cannot put the information into context with their own aircraft and expected landing time.

2. Misinterpretation of weather information by air traffic control personnel to determine runway use could result in inappropriate operational decisions.

3. Errors in automatic terminal information service (ATIS) generation could result in a situation where flight crews are making in-flight decisions based on incorrect or missing information.

4. Airport grid maps were available in both the tower and ground vehicles, but were neither required nor used to provide coordinates for the aircraft's position. This could result in confusion as to aircraft position and delays in rescue response in other occurrences.

5. The *WestJet Flight Operations Manual* performance charts for Canadian runway friction index (CRFI) restricted runways are predicated on an autobrake setting of Max, but the flight operations manual does not define CRFI restricted runway. It is possible that the flight operations manual description of autobrake settings 2 or 3 could lead crews to use those settings where the use of autobrake setting Max would be more appropriate.

Other Finding

1. The Ottawa International Airport decelerometer equipment was not checked following the occurrence to determine calibration status.

Safety Action Taken

NAV CANADA

NAV CANADA issued direction in the form of an operations letter to remind controllers of the *Air Traffic Control Manual of Operations* (ATC MANOPS) requirement to use the proper format when issuing runway conditions and braking action reports. This operations letter was the subject of a mandatory verbal briefing. In addition, the Winter Operations Bulletin, issued nationally, contains a clear reminder to use techniques and phraseology in accordance with the ATC MANOPS and the NAV CANADA *Flight Services Manual of Operations (*FS MANOPS) to enhance positive, effective two-way communications.

On 25 February 2008, an operations bulletin was published, stating "Upon receipt of an Airfield Condition Report, Clearance Delivery shall make two copies of the report and provide one copy to ground control and one copy to airport control." Local Procedures, paragraph 200.1 j, were amended accordingly. This measure ensures that as soon as a report is received via fax, the controllers are made aware of it.

The Ottawa Tower conducted a thorough review of airfield condition reports using a database covering a two-month (winter) period to identify discrepancies between the English and French vocabularies stored in the system. Digital automatic terminal information service (ATIS) functionalities have been reviewed and the necessary corrections have been made to the English/French vocabulary. The controllers have also been provided with instructions on how the vocabulary can be amended locally, if required.

WestJet

Minimum equipment list (MEL) 78-1 thrust reverser inoperative has been amended to read: "When calculating landing distance required, 20% shall be added to flight landing distance calculations". The baseline calculated landing distances do not give credit for reverse thrust.

An aircraft communications addressing and reporting system (ACARS) landing distance calculator for landings in normal conditions has been added. The ACARS system can be used in conjunction with braking reports or Canadian runway friction index (CRFI) information. When a CRFI is entered, the calculations are based on Max autobrake.

In consultation with the aircraft manufacturer (sections 10A, 10B, and 10C — Landing Performance Data), the note advising the autobrake setting to be used when landing on runways with CRFI information available has been revised. Until now, autobrake settings less than Max were permitted if "optimum conditions" were present. This has been removed as

accurate landing distance information is not always available for landings on runways with CRFI information available for autobrake settings less than Max. As a result, regardless of other conditions, the autobrake will now always be set to Max when landing on a runway with CRFI information available.

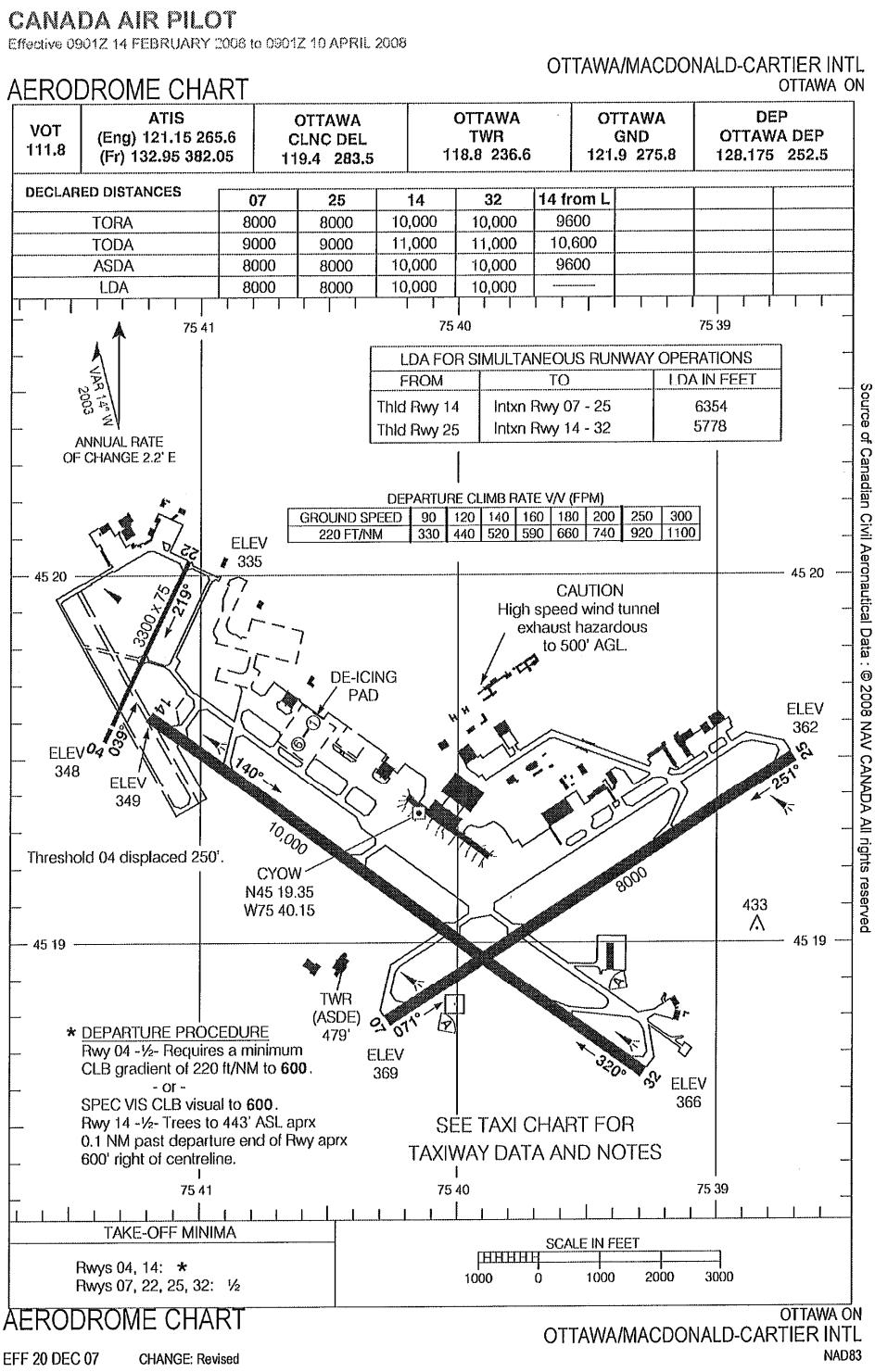
The 2009 recurrent ground training will make reference to this incident in regards to overload, fixation, and strategies to recognize and mitigate those conditions. The discussion will be organized around the flight data animation of the flight as it progressed, with specific focus on:

- initial plan, briefing and performance calculation (CRFI/runway surface condition);
- runway change and process followed to accommodate that change including landing performance;
- flight profile and strategy employed in energy management and configuration;
- stable approach criteria and threat associated with continuing an unstable approach (Refers to WestJet Airlines flight data monitoring (FDM) unstable approach numbers);
- phenomenon of workload and the resultant "fixation" and "single channel of attention" as it applied to this crew (missed 1000' call, speed brake not armed):
    - reference to Southwest Airlines accidents at Burbank and Chicago Midway airports and impact of fixation
    - reference information gathered by WestJet gatekeepers in pilot unstable approach debriefs (FDM program)
    - how to recognize and manage the phenomenon of fixation / single channel; and
- actual excursion and management of air traffic control, aerodrome emergency services, flight attendants, and passengers will be discussed in joint crew resource management

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 10 March 2009.

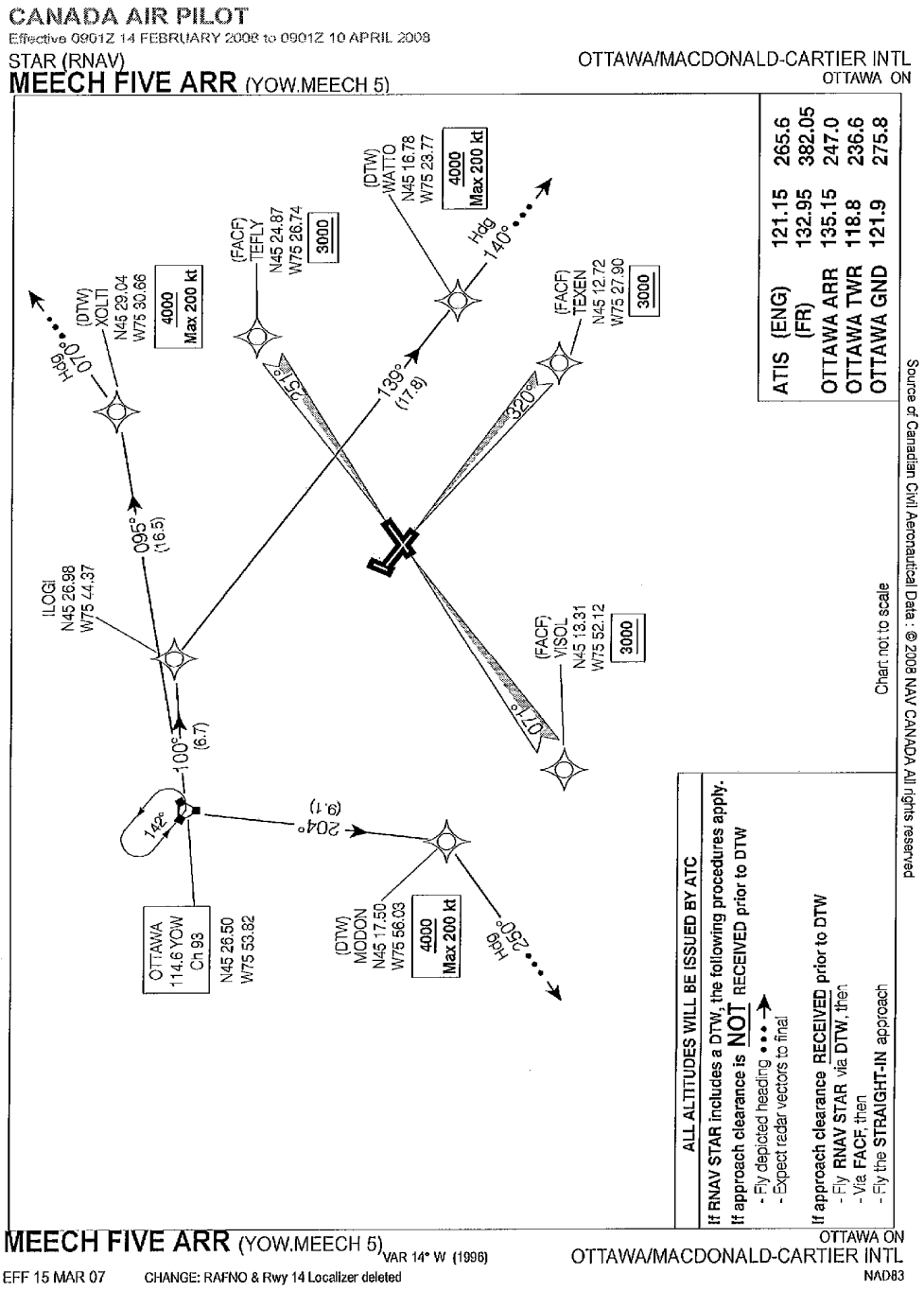
*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A – Ottawa Airport Diagram



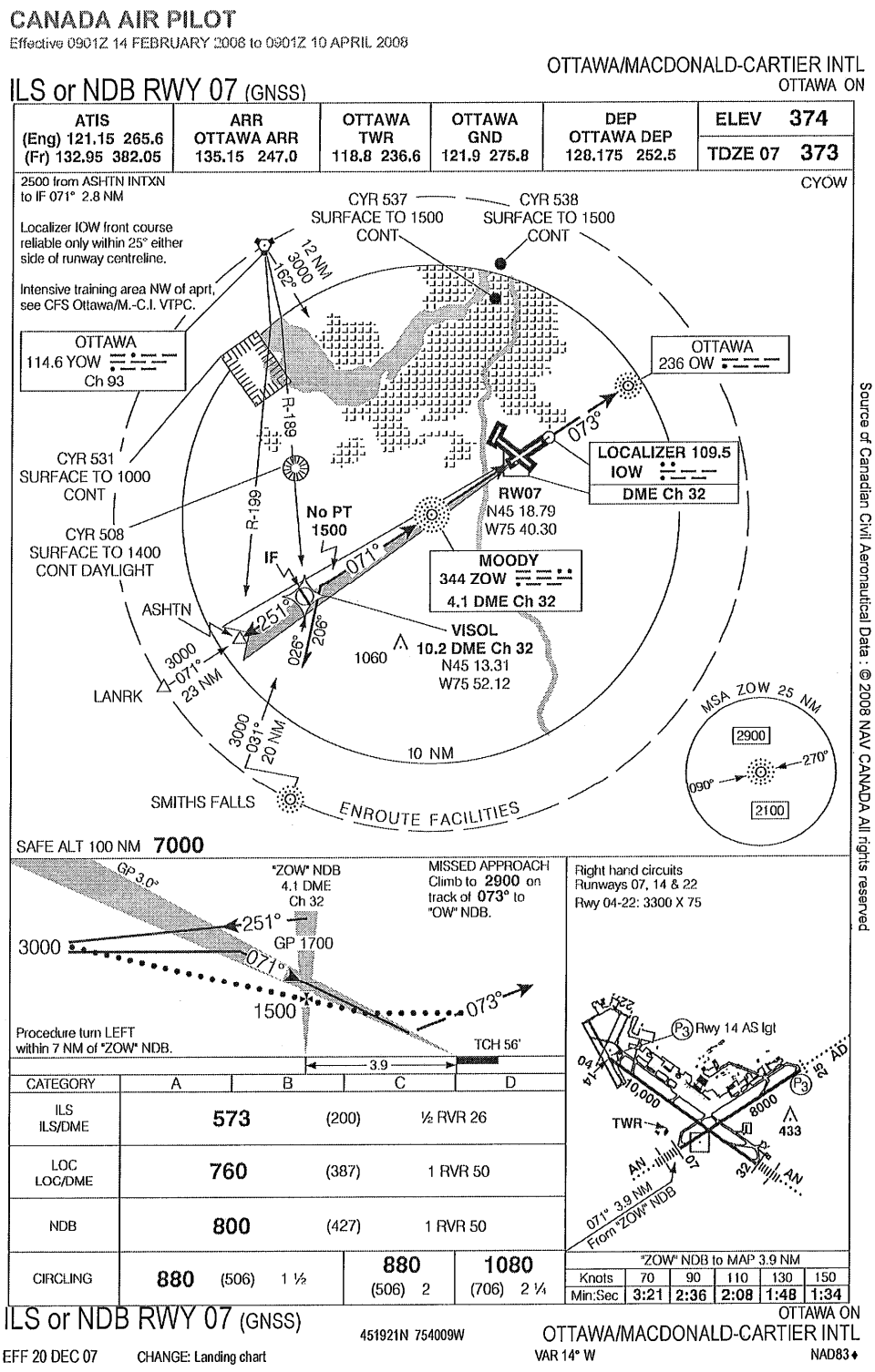
NOT TO BE USED FOR FLIGHT PLANNING PURPOSES

Appendix B – Meech Five Arrival



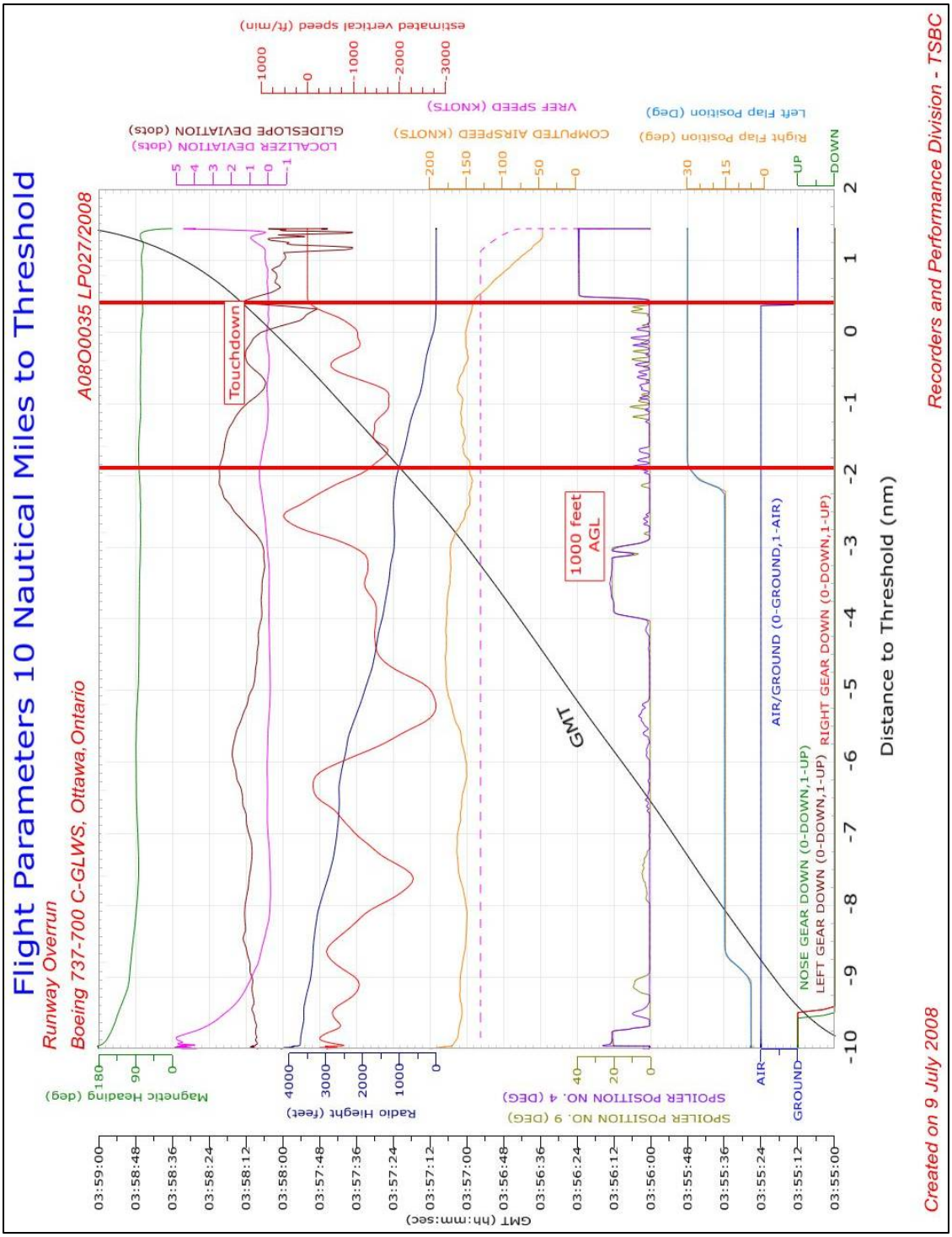
NOT TO BE USED FOR NAVIGATION PURPOSES

Appendix C – Instrument Landing System (ILS) Approach, Runway 07, Ottawa



NOT TO BE USED FOR NAVIGATION PURPOSES

Appendix D – Flight Data Recorder Plot, Last 10 Nautical Miles



Note: To ascertain time, move vertically from the event line to the GMT (Greenwich mean time) line. Then, move horizontally to the far left margin to read time.