

Investigation Report

EX006-0/05
January 2007

Identification

Type of occurrence:	Serious incident
Date:	14 August 2005
Location:	Hanover
Aircraft:	Transport aircraft
Manufacturer / Type:	Embraer / EMB-145 EP
Injuries to persons:	One person with minor injuries
Damage:	Minor damage to aircraft
Other damage:	Crop damage
Information Source:	Investigation by BFU

METAR from 15:50 hrs valid until 16:20 hrs. According to this information runways 27R and 27L were in service. The crew opted for the shorter runway 27L because of the construction work going on on taxiway G and the shorter distance to the terminal.

Based on the weather forecast thunderstorms and heavy rain showers were to be expected for the time of the landing. The crew assumed that they would have a regular landing on a wet runway because neither air traffic control service nor ATIS had given any indication of limited braking action.

The wind was blowing from a southerly direction shifted, however, to south-east to east during the approach and landing.

From 16:08 hrs to 16:33 hrs four special weather reports (SPECI-METARs) were broadcast via ATIS because of the rapidly changing weather. However, the crew did not receive these reports any more.

Factual information

History of the flight

On 14 August 2005 at 16:51 hrs¹ an Embraer EMB-145 EP had overshot the end of runway 27L at Hanover airport. One flight attendant suffered minor injuries and the aircraft was slightly damaged in the area of the landing gear. Crop damage occurred.

The airplane had left Birmingham at 15:20 hrs for a scheduled flight to Hanover with 45 passengers and four crew on board. The crew had decided to take 200 kg of extra fuel along because thunderstorms were to be expected in Hanover.

During the approach to Hanover the crew listened to the prevailing weather broadcasted by Hanover

The approach procedure started north of the airport. During the descent the crew encountered individual thunder cells which were visible on the on-board radar and flew around them. Thereby the aircraft encountered icing conditions for a short period of time.

The airplane was instructed to descent to 2,000 ft. At this altitude they captured the ILS (Instrument Landing System) for runway 27L. According to crew statements it was raining very heavily at that time. They had to increase the windshield wipers' speed. During the approach speed was approximately 160 kt. According to crew statements the approach lights became visible at a distance of about 4 NM from the runway.

¹ Unless otherwise specified, all times are indicated in local time

In approximately 500 ft the airplane had assumed landing configuration: Flaps were fully extended (45°) and speed was 140 kt.

In 180 ft the autopilot was disengaged and the pilot-in-command flew the airplane manually. The visual glide slope (PAPI) was in service and according to crew statements the airplane was in the required altitude.

A tailwind of about 3 kt prevailed during the landing since wind direction had changed to the south-east because of the shower and thunderstorm activity.

According to crew statements the airplane crossed the threshold with about 140 kt. It touched down within the touchdown zone.

The crew did not experience any significant deceleration of the airplane even though the ground spoilers had automatically deployed after touch down.

The pilot-in-command had tried to decelerate the airplane but in vain. He instructed the co-pilot to help him with the brakes. This, too, was unsuccessful.

Shortly before the airplane overshot the runway the pilot-in-command activated the parking brake which is also the emergency brake. This resulted in a deactivation of the anti-skid system, the wheels locked up and the ground spoilers retracted.

After fishtailing a few times around the runway centre line the airplane overshot the right-hand end of the runway with a speed of about 70 kt and came to a stop on unpaved terrain about 160 m beyond the end of the runway (see Appendix 1).

Eyewitnesses stated that the airplane touched down close to a small access route which meets the runway about 1,000 m after the threshold.

Personnel information

Pilot-in-command

The 60-year-old pilot-in-command held a British Airline Transport Pilot Licence (ATPL(A)) issued on 16 May 1997 and valid until 15 May 2007. An extension occurred every 6 month and was valid at the time of the occurrence. He was type rated as pilot-in-command for Embraer EMB-145 and DH-8 and IFR CAT III. He was an instructor for EMB-145 and DH-8 simulators and for DH-8 aircraft.

His total flight time was 9,800 hours, of which about 2,937 hours were on Embraer.

Flight time in the 24 hours prior to the occurrence was 1 hour and 30 minutes at a total work time of about

2 hours and 30 minutes. In the past 90 days he had flown about 170 hours. He had a 10-day rest period prior to the occurrence.

His medical certificate was valid until 21 November 2005. He was required to wear glasses.

Second pilot

The 32-year-old pilot held a British Airline Transport Pilot Licence (ATPL(A)) issued on 25 June 2003 and valid until 24 June 2008. An extension occurred every 12 month and was valid at the time of the occurrence. He was type rated as co-pilot for the Embraer EMB-145 and DH-8.

His total flight time was 3,152 hours, of which 2,221 hours were on Embraer EMB-145.

Flight time in the 24 hours prior to the occurrence was about 3 hours and 30 minutes at a total work time of about 5 hours and 30 minutes. In the past 90 days he had flown about 160 hours. He had an 18-hour rest period prior to the occurrence.

His medical certificate was valid until 30 November 2005. He was required to wear glasses.

Aircraft information

The aircraft is an Embraer EMB-145 EP manufactured by Embraer in Brazil. The aircraft with the MSN 145-039 had two Rolls Royce AE 3007/A1/1 engines without thrust reversers installed on the rear fuselage. Total operating hours were 16,681 hours and 49 minutes with 13,196 flight cycles. The airplane had a certificate of registration and was subject to a regular maintenance cycle.

The British Civil Aviation Authority had issued a certificate of registration on 10 January 2003.

Maximum take off-weight was 20,990 kg. The actual take-off weight was 19,783 kg. Maximum landing weight was 18,700 kg. At the landing in Hanover it was 18,334 kg. The load sheet showed that the centre of gravity was within limits.

The aircraft technical logbook showed performance of an intermediate check after the flight the day before and a company engineering pre-service inspection prior to the flight on 14 August 2005.

The airplane was equipped with four B F Goodrich braking units (P/N 2-1582). Installation of the braking units and mounting of the tyres took place between January and July 2005.

The data recorded by the braking computer was analysed after the occurrence. It did not show any malfunction of the brakes.

At the time of the occurrence the aircraft technical logbook did not show any irregularities regarding the brakes or tyres.

The tyre pressure of the main landing gear's tyres was 148-0/+5°PSI which is within the limits required by the Aircraft Maintenance Manual (AMM).

This aircraft type is equipped with an automatic ice warning system. The Engine Indication and Crew Alerting System (EICAS) indicates icing conditions as soon as the ice warning system has detected them and stall speed is increased by 5 to 7 kt by the stall protection system. This increase of the Stall Protection System Speed (SPS/SPEED) cannot be reversed during the flight due to the software.

Performance

Landing distance calculation

The landing distance was calculated based on specifications given in the Airplane Flight Manual (AFM) and with the following conditions:

The elevation of Hanover Airport is 183 ft. For calculation purposes an airport pressure altitude of 200 ft was used. Static air temperature was +15°C and wind velocity 100°, 5 kt which resulted in a tailwind of approximately 3 kt. The landing distance available (LDA) for Hanover's runway 27L is 2,340 m. The aircraft's actual landing mass was 18,334 kg.

For the calculation of the reference speed V_{Ref} the following data was used: a gross weight of 18,000 kg, an approach flap setting of 9° and a landing flap setting of 45°. This resulted in a V_{Ref} of 130.6 kt and a V_{Ref+5} of 135.6 kt (AFM page 5-195). Actual overflight speed at the threshold (V_{Ref}) was 140 kt.

The access data for the Field Length Limited Chart are static air temperature +15°C and airport pressure altitude 200 ft, which results in an unfactorised landing distance of 880 m (AFM pages 5-248 to 5-249) on a dry, solid and even runway. This leads to the following factorised distances for different runway conditions (AFM page 5-250), normal dry 1,470 m (factorised with 1.67 see JAR-OPS 1.515), normal wet 1,690 m (factorised with 1.92 see JAR-OPS 1.515 and 1.520) and with 10 kt over speed and wet 1,487 m (factorised with 1.69 see AFM page 5-199).

The next step investigates operation on contaminated runways (AFM Supplement 11) because the runway condition is not clearly known. The input quantities are a gross weight of 18,000 kg, a landing flap setting of

45°, an over speed of 5 kt IAS, a static air temperature of +15°C, a tailwind of 3 kt, an airport pressure altitude of 200 ft and a runway slope of 0°. For different water depths (pages S11-52F and S11-53) the data results in the following unfactorised landing distances: 1,920 m (3 mm water depth), 1,830 m (5 mm water depth) and 1,720 m (10 mm water depth). Factorised with 1.15 (see JAR-OPS 1) it results in 2,208 m (3 mm water depth), 2,104 m (5 mm water depth) and 1,978 m (10 mm water depth).

Meteorological information

Prior to departure in Birmingham the crew had weather information for Hanover Airport and its surrounding airports available to them. The weather forecast of 14 August 2005, valid from 12:00 UTC until 14:00 UTC, predicted a 30% chance of thunderstorm and rain.

During the flight the crew obtained the weather information "P" of 15:50 hrs valid until 16:20 hrs via the ATIS frequency 132.12 MHz of Hanover Airport.

- Runways 27L and 27R in service and so are the respective ILSs.
- Transition Level 70
- Wind: 150° / 5 kt
- Visibility: 8 km, light rain
- Clouds: FEW 800 ft, SCT 2,000 ft, BKN 3,400 ft.
- Temperature/Dewpoint: 15°C / 15°C
- QNH: 1,009 hPa
- There were no significant weather changes to be expected

The weather deteriorated during the approach. That is why ATIS broadcast so called special weather reports (SPECI-METARs) at 16:08 hrs, 16:14 hrs, 16:21 hrs and 16:33 hrs. The report broadcast at 16:33 hrs reported wind velocity 140°, 5 kt, visibility 1,800 m and heavy rain.

At the time of the landing wind velocity had changed to 100° and 5 kt. Visibility was 2,000 m and it continued to rain heavily. The cloud base was at 1,100 ft.

Aids to navigation

For the approach to Hanover Airport the ILSs for runways 27L and 27R were in service. Furthermore, the NDB for 27R HA and both DME – HAD and HBD – were available.

For runway 27L the Precision Approach Path Indicator (PAPI) was also available.

Communication

All radio communications between crew and air traffic control service Hanover were recorded. The BFU

conducted an evaluation of the recordings. Radio communications were held in English.

Aerodrome information

Hanover Airport has an elevation of 183 ft and has two parallel runways running in East - West direction (92°/272°) (see Appendix 2). The northern runway has a length of 3,800 m and the southern runway a length of 2,340 m. Both runways have a width of 45 m. Taxiways K, Kto and G were closed due to construction work.

Runway 27L (southern runway) has a concrete surface and was cleaned of rubber deposit on 26 July 2005. It does not have a stop way

At the time of the landing it was raining. The runway was wet and showed patches of standing water. At 17:03 hrs, after the occurrence, braking action was determined. In the first third of runway 27L braking coefficients varied between 0.40 and 0.70. In the middle third and the last third of the runway braking coefficients were between 0.60 and 0.70 (good) (see Appendix 3).

According to airport control procedures the aerodrome operator has the obligation to ensure proper conditions of all operating areas and to inform aerodrome control tower of current conditions.

A B737 crew had landed prior to the EMB-145 and reported to the BFU that braking action on runway 27L was medium due to water.

Flight recorders

The airplane was equipped with a Honeywell Digital Flight Data Recorder (DFDR) and a Honeywell Solid State Cockpit Voice Recorder (SSCVR). Both recorders were in serviceable condition and evaluated by the BFU.

The recorders' data and the statements of the pilots were fairly consistent.

In order to determine the touchdown point a parameter was introduced and called "distance". It was calculated from the airplane's speed. The aircraft touchdown point was plotted from the middle marker distance versus time. Starting point was the overflight of the middle marker. The distance middle marker – runway threshold was 0.6 NM or 1,111 m. 12 seconds after the overflight of the threshold the airplane's landing gear touched down. The airplane had travelled a distance of 849 m during that time.

For the reconstruction of the flight path according to the flight data recorder please refer to Appendix 4.

- An ILS approach with engaged autopilot to runway 27L was conducted. The airplane had become established and assumed landing configuration in 500 ft.
- The autopilot was disengaged at an altitude of 180 ft. The airplane remained above the ILS glide slope from then on.
- Overflight altitude of the threshold was 62 ft with a speed of 140 kt.
- After crossing the threshold descent speed was decreased continuously. N1 decreased from 59% to 25% idle power at the time of touchdown.
- Touchdown speed was 122 kt.
- At the time of touchdown the ground spoilers deployed automatically.
- During a period of 17 seconds the left-hand main landing gear's brake pressure increased to about 350 PSI. On the right-hand side short peaks of up to 600 PSI were reached.
- Deceleration was -1.8 g shortly after touchdown and decreased to -0.5 g at the end of the runway.
- The airplane's course varied between 266° and 282°.
- About eight seconds prior to reaching the end of the runway the emergency brake (parking brake) was activated and brake pressure increased to 2,600 PSI. The ground spoilers retracted since the tyres had locked. At this time, speed was still 68 kt.
- The airplane overshot the end of the runway with about 58 kt and came to a stop about 11 seconds later.

Wreckage and impact information

The accident site was surveyed and transferred to a map (see Appendix 1). The ground beyond the runway was soft which meant that the airplane sunk into the ground up to its axles which in turn resulted in a strong deceleration. On the right-hand main landing gear a wheel well door was torn off.

All four tyres of the main landing gear showed traces of rubber reversion hydroplaning, a certain form of aquaplaning.

All four tyres had left about 400-meter-long bright traces on the runway which were definitely caused by rubber reversion hydroplaning. Furthermore, melted-away rubber was found on the runway (see Appendix 5).

The tyre pressure of 148-0/+5 PSI required by the manufacturer was adhered to.

Fire

There was no evidence of fire.

Additional information

With this aircraft type the parking brake is also the emergency brake. An ON/OFF switch controls brake pressure from zero to maximum. If the parking/emergency brake is activated up to 3,000 PSI affect the brake abruptly and lock up the tyres. At the same time the anti skid system is deactivated.

Operational procedures

The Aircraft Operation Manual (AOM), Part B describes the landing technique for contaminated or wet runways. It includes the following:

When hydroplaning occurs, it causes a substantial loss of tire friction and wheel spin-up may not occur.

- The approach must be flown with the target of minimizing landing distance.
- The approach must be stabilized, and landing on centreline in the touch down zone.
- The touchdown should be firm to penetrate the contaminating fluid film, and ensure wheel spin-up and spoiler activation.
- Immediately after touchdown, check the ground spoiler automatic deployment when thrust levers are reduced to IDLE.
- Lower the nose wheel positively, with forward pressure to assist traction and directional stability.
- **Apply brakes with moderate-to-firm pressure, smoothly and symmetrically, and let the anti-skid do its job.**
- **If no braking action is felt, hydroplaning is probably occurring. Do not apply Emergency- / Parking brake, as it will cause the spoilers to close and cut the antiskid protection. Maintain runway centreline and keep braking until airplane is decelerated.**

Analysis

Technical Aspects

The technical examination of the braking system including brake units and tyres did not determine any signs that the runway overshoot was caused by dysfunctional brakes.

Airport

The braking coefficients determined about 15 minutes after the landing show good braking conditions at the time of the survey. However, since it had stopped raining at that time the coefficients do not reveal anything about the braking conditions at the time of the Embraer's landing.

To allow for the quickly changing weather SPECI-METARs were broadcast via ATIS. However, there was no information on runway conditions or the estimated braking conditions. The crew did not receive information on runway conditions through Hanover TWR either.

It is furthermore to be stated that the aerodrome controller did not have sufficient information regarding runway conditions. The aerodrome operator should have provided this information because he is obliged to provide aerodrome control service (Deutsche Flugsicherung, DFS, German Air Traffic Control Service) with all information necessary for the safe conduct of flight operations. The Manual of Operations Air Traffic Control Services (BAFVK) states under point 314.28 Note: It is the responsibility of the aerodrome operator to provide the aerodrome control tower with current information on aerodrome conditions.

According to BAFVK point 221.23 the aerodrome controller shall perform the following tasks: To transmit information required for the safe, orderly and expeditious conduct of flights, such as: *Essential aerodrome information*.

BAFVK point 314.2 explains essential aerodrome information: *Essential aerodrome information is information concerning the condition of the movement area and associated facilities which is necessary for the safe operation of aircraft. It shall be issued whenever deemed necessary by the controller on duty in the interest of safety, or when requested by a pilot. ... It shall include the following information, as appropriate:*

Point 314.23: Snow, slush, ice or water on a runway, a taxiway or an apron.

Point 314.231: Whenever water is present on a runway, a description of the runway surface conditions

on the centre half of the width of the runway, including the possible assessment of water depth, where applicable, should be made available using the following terms:

Damp: The surface shows a change of colour due to moisture;
Wet: The surface is soaked but there is no standing water
Water patches: Significant patches of standing water are visible;
Flooded: Extensive standing water is visible.
 Point 314.232: Pilot reports about the braking action shall be transmitted to approaching aircraft, the validity of the message shall be taken into consideration.

A B737 crew landing prior to the EMB-145 had stated in a later conducted interview that the braking action had been medium due to standing water but they had not informed the aerodrome controller. Such information is of paramount importance to approaching aircraft because it helps the crews to better prepare for the imminent landing. Therefore such information should promptly be reported to the aerodrome controller so that he can immediately transmit them to other crews.

Because of the rain which had lasted for several days and the high humidity runway surface and ground were saturated with water and did not dry very well. Based on the weather situation an aerodrome operator should inspect runways in short intervals in order to give approaching crews more current information on runway conditions.

The traces on the runway and the melted-away rubber on all four tyres of the main landing gear indicate aquaplaning. Of special interest are the last approximately 800 m prior to the end of the runway. All four main landing gear tyres left bright marks which look like they might originate from steam blasting. These tyre tracks in connection with the marks on the tyres themselves indicate a rare form of aquaplaning the so called rubber reversion hydroplaning. In this case it occurred when the emergency brake was activated, the anti-skid system was deactivated and the tyres locked.

This kind of aquaplaning can already occur on damp runways. Rubber reversion hydroplaning is caused by friction-generated heat which produces superheated steam at high pressure. High temperature causes the rubber to revert to its uncured state which forms a seal around the tyre area. This seal traps the high pressure steam. This can already occur below the usual aquaplaning speed.

Based on the slow deceleration after touchdown it is highly likely that dynamic aquaplaning occurred in the middle part of the runway.

Operational aspects

With the benefit of hindsight, the crew's decision to land on the 2,340-meter-long runway 27L because taxiways K, Kto and G were under construction and the distance to the terminal was shorter even though the 3,800-meter-long runway 27R was also available turned out to be a disadvantage.

If limited braking action or aquaplaning is to be expected the longest available runway should be used.

This is especially true for aircraft without thrust reversers because if aquaplaning occurs the crew's only option is to wait until speed has decreased through drag and friction to such an extent that wheel grip has returned and wheel brakes can be used again.

Compared to this aircraft type, aircraft with thrust reversers have an advantage when aquaplaning occurs because with the help of thrust reverser speed can be reduced rather quickly.

Landing distance calculation

Because the runway condition could not be reconstructed with absolute certainty the calculation of the landing distance includes different kinds of scenarios.

The landing distances required differ between 1,470 m and 2,208 m in the worst case scenario. Based on the actual braking distance the BFU is of the opinion that in all probability the runway was contaminated with water which would have required a landing distance of 2,208 m. With an available landing distance of 2,340 m only about 150 m remain. This reserve is used up rather quickly if the specified parameters are not adhered to. The BFU is therefore of the opinion that a decision to take the longer northern runway would have been a better one.

After the pilot-in-command had taken over controls and flew the airplane manually the airplane left the 3° glide slope and the overflight height over the threshold was 62 ft instead of the specified 50 ft.

Overflight speed over the threshold was 140 kt and therefore 10 kt faster than the calculated V_{ref} for the actual landing mass. Incorporating the ground effect a longer flare landing was thereby aided.

Touchdown of the airplane 1,000 ft (300 m) after approach end of runway is for the landing distance calculation ideal but in practise barely accomplishable.

The real touchdown point was 849 m after the threshold which meant that braking distance was shortened by 500 m and was therefore not long enough anymore for the airplane to come to a stop on the runway.

The manufacturer stipulated that in case of aquaplaning the emergency brake was not to be used because its activation deactivates the anti-skid system. As a result the tyres lock up which aids aquaplaning. The pilot-in-command used the emergency brake wrongly assuming that the braking system had failed which would have justified the use of the emergency brake. However, a corresponding failure indication did not exist.

Conclusions

Findings

- Both pilots held the necessary licenses and ratings required for the conduct of the flight. Due to their total flight experience and their flight experience on the type, the pilots were to be considered experienced and qualified.
- The airplane was properly certificated and maintained in accordance with existing regulations and approved procedures.
- A technical cause for the runway overshoot could not be determined.
- According to the information contained in load sheet and trim sheet the landing mass and the centre of gravity were within limits.
- This airplane is not equipped with thrust reversers and has therefore no option to reduce speed with their help in case of aquaplaning.
- The landing occurred with a 3 kt tailwind which increased the required landing distance.
- In theory, runway 27L would have been long enough had all parameters used for the calculation been adhered to. However, the airplane touched down 849 m after the threshold which resulted in the fact that the LDA was theoretically and practically insufficient given the prevailing conditions.
- It is the BFU's opinion that the increase in SPS/SPEED during flight to counteract icing conditions can only be reversed on the ground is a disadvantage where LDR is concerned.
- Based on the slow deceleration, the BFU is of the opinion that dynamic aquaplaning occurred shortly after touchdown in the middle part of the runway. A soft landing on a runway contaminated with water aided aquaplaning.
- The BFU is of the opinion that rubber reversion hydroplaning occurred on a length of about 800 m because of the marks left on the runway and on all four tyres of the main landing gear.
- The use of the parking/emergency brake during aquaplaning is contradictory to the procedures defined in the AOM Part B. This caused the rubber reversion hydroplaning.
- The crew was neither informed about the actual runway condition by ATC nor through the METARs broadcast by ATIS.
- The aerodrome operator did not provide the tower controller with required information on runway conditions necessary for a safe conduct of flight operations.
- A continuous observation and assessment of the runway conditions through the aerodrome operator which the quickly changing weather situation would have made necessary did not occur.

Cause

Causal factors for the runway overshoot were:

- The decision to land on the shorter runway which was aided by insufficient information regarding the real runway condition.

- The late touchdown which was caused by insufficient situational awareness, light tailwind and increased landing speed.
- The missing braking action which was caused by aquaplaning. The use of the emergency brake which aided aquaplaning.

Safety Recommendation

The operator involved recommended the following measures:

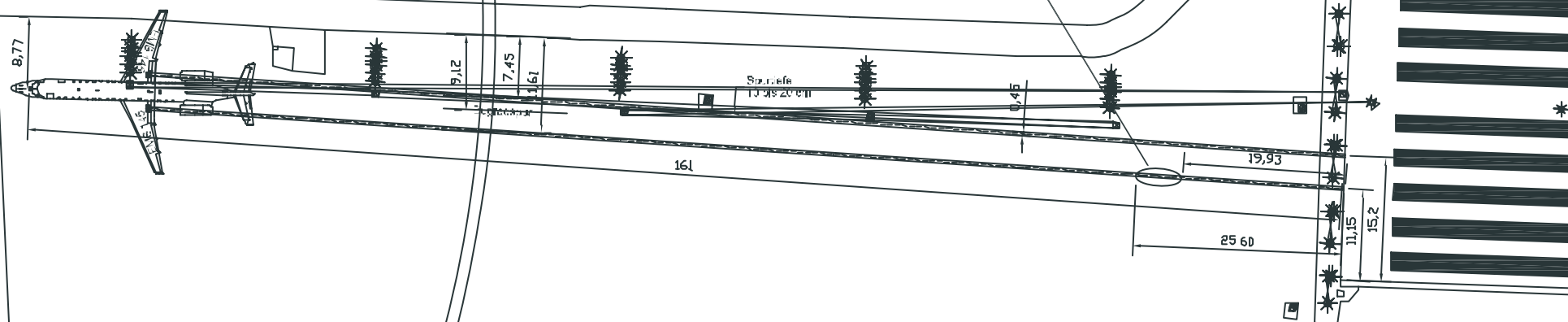
1. A review of the way in which pilots on the EMB-145 might be reacquainted with the importance of using the correct landing technique on wet runway should be made.
2. A review of guidance provided to flight crew for circumstances where braking effectiveness during landing is not sufficient should be undertaken.
3. A review should be made of the circumstances under which aquaplaning can occur on wet runways so as to better inform the management of this risk.

Based on the described actions the BFU will abstain from safety recommendations.

Investigator-in-charge	Müller
Assistance	
Flight recorder read-out	Thiel
Performance	Nehmsch

Appendices

Appendix 1	Site plan
Appendix 2	Aerodrome chart
Appendix 3	Braking action measurement
Appendix 4	Flight recorder read-out
Appendix 5	Photographs



Lageplan
Flugunfall 14.08.05

Bearb.		Datum	15.08.05				
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Enclosure 2

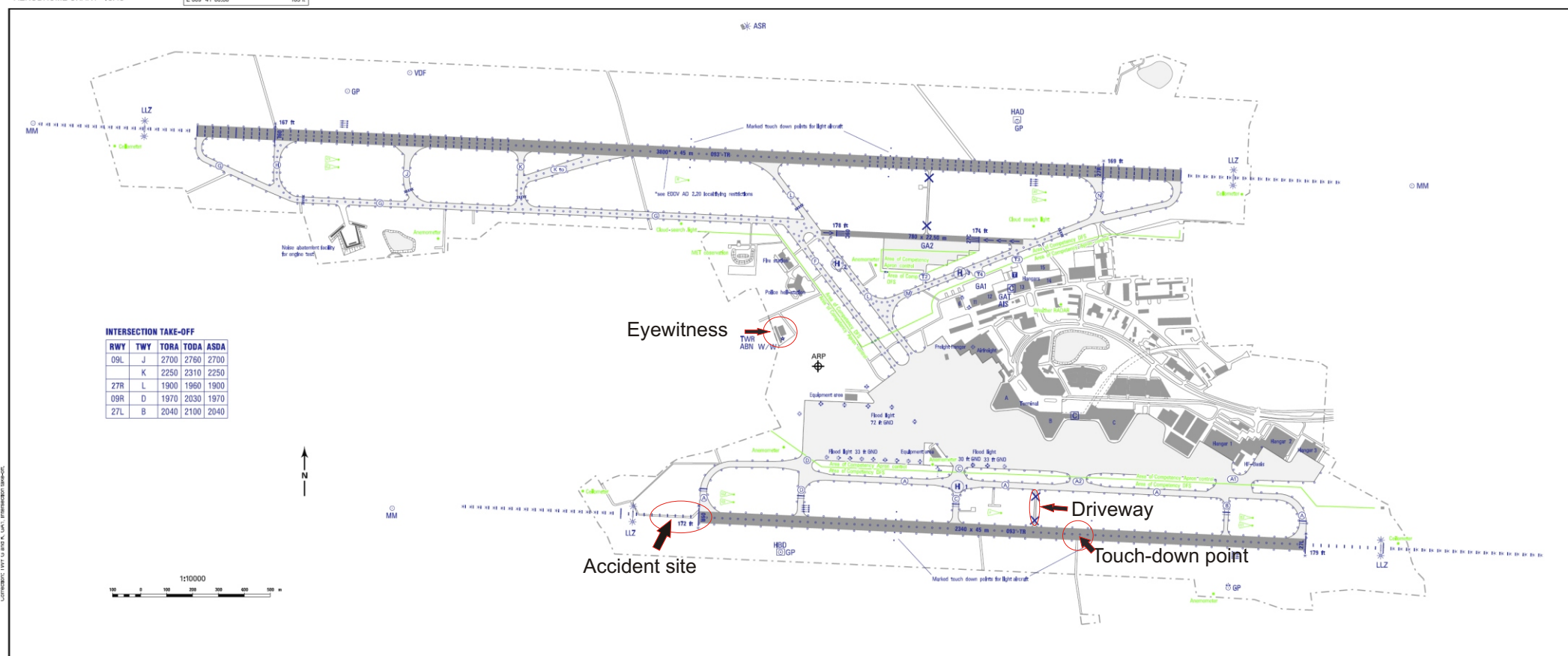
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AIP GERMANY

FLUGPLATZKARTE - ICAO
AERODROME CHART - ICAO

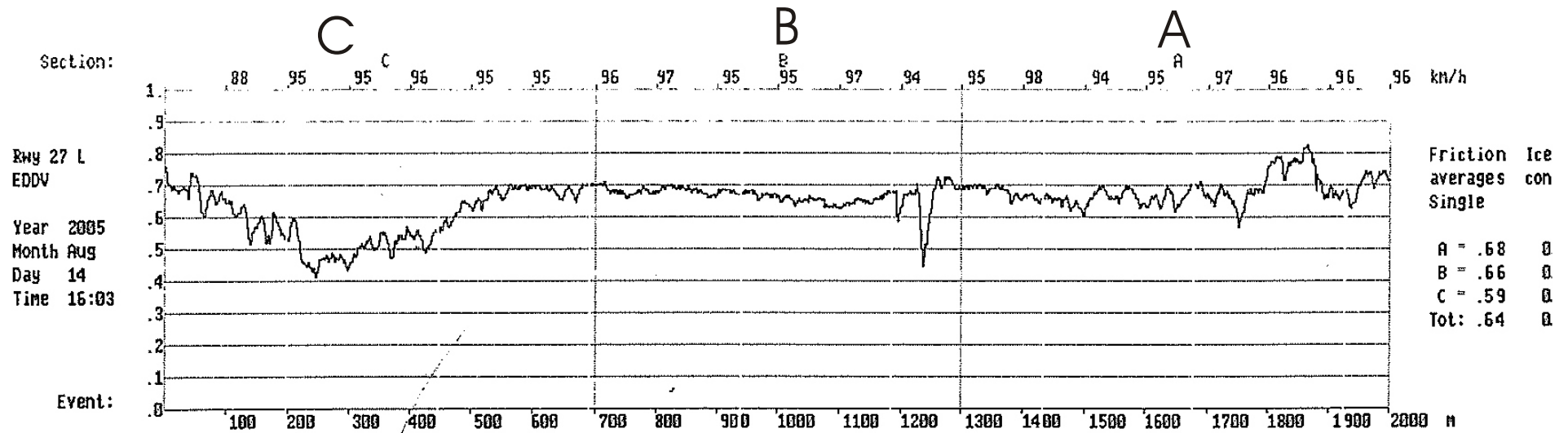
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AERODROME
ELEVATION
183 ft

AD 2 EDDV 2-5
16 FEB 2006

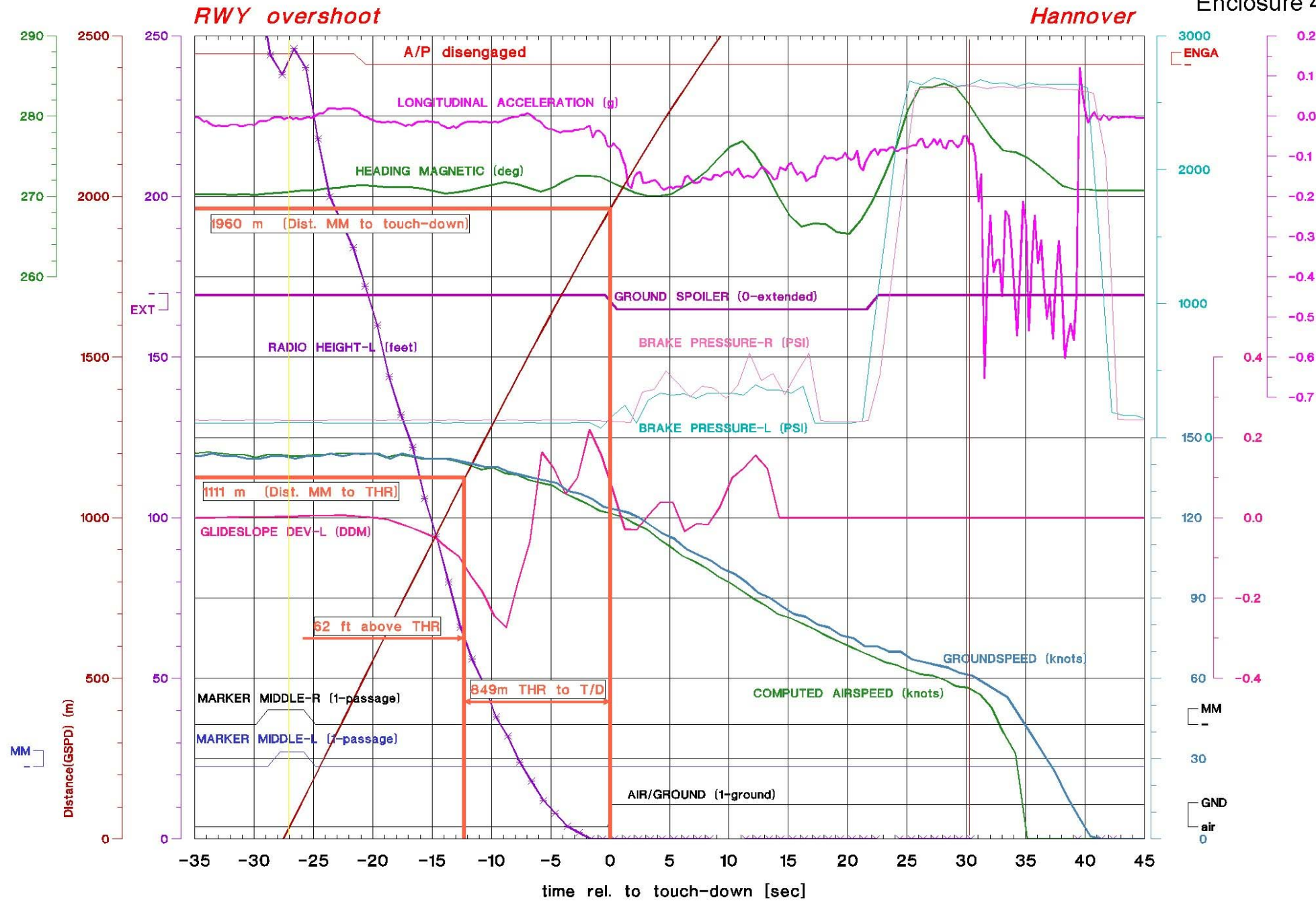
HANNOVER



Landingdirection 27L



Brakingaction messurement



Enclosure 5



Marks of Rubber Reversion Hydroplaning
on the tire



Marks of Hydroplaning on the runway



Rubber damped from tire