INCIDENT REPORT

Runway Excursion Incident

Boeing 777-200 Registration 9V-SRG

Singapore Changi Airport

24 January 2004

AIB/AAI/CAS.016

Ministry of Transport
Singapore

26 April 2005

The Air Accident Investigation Bureau of Singapore

The Air Accident Investigation Bureau (AAIB) is the investigation authority in Singapore responsible to the Ministry of Transport for the investigation of air accidents and incidents to Singapore and foreign civil aircraft in Singapore. The AAIB also participates in overseas investigations of accidents and incidents involving Singapore aircraft or aircraft operated by a Singapore air operator.

The mission of the AAIB is to promote aviation safety through the conduct of independent and objective investigations into air accidents and incidents consistent with Annex 13 to the Convention on International Civil Aviation.

The AAIB conducts the investigations in accordance with the Singapore Air Navigation (Investigation of Accidents and Incidents) Order 2003 and Annex 13 to the Convention on International Civil Aviation, which governs how member States of the International Civil Aviation Organization (ICAO) conduct aircraft accident investigations internationally.

The investigation process involves the gathering, recording and analysis of all available information on the accidents and incidents; determination of the causes and/or contributing factors; identification of safety issues; issuance of safety recommendations to address these safety issues; and completion of the investigation report.

In carrying out the investigations, the AAIB will adhere to ICAO's stated objective, which is as follows:

> *"The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability."*

CONTENTS

GLOSSARY OF ABBREVIATIONS

ATC	Air Traffic Control
ATIS	Aerodrome Terminal Information Service
CAS	Calibrated Air Speed
CRM	Crew Resource Management
DFDR	Digital Flight Data Recorder
FO	First Officer
IAS	Indicated Airspeed
ILS	Instrument Landing System
ICAO	International Civil Aviation Organisation
PIC	Pilot-In-Command
SARP	Standard and Recommended Practices
SOP	Standard Operating Procedures
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
Vref	Minimum speed based on a percentage of the stall speed of aircraft

BOEING 777-200, 9V-SRG

Classification	:	Incident
Aircraft type	:	Boeing 777-200
Registration	:	9V-SRG
Number and Type of Engines	:	Two Rolls Royce Trent 800
Place	:	Singapore Changi Airport
Date & Time (Local Time)	:	24 January 2004, 2035 hours
Type of Flight	:	Public Transport (Passenger)
Persons on Board	:	269
Point of Departure	:	Brisbane, Australia
Destination	:	Singapore Changi Airport

SYNOPSIS

A Boeing 777-200 aircraft was landing in rain at the Singapore Changi Airport on 24 January 2004, when its left hand landing gear momentarily departed the paved surface of Runway 02L and went onto the soft grass verge before returning to the paved runway surface. Subsequently, the aircraft taxied on its own to the designated passenger gate. All occupants disembarked unassisted using the aerobridge. There was no injury.

All six tyres of the left hand landing gear showed evidence of reverted rubber aquaplaning and three of the tyres were deflated. The forward and aft junction boxes under the landing gear truck were damaged and separated from their attachments.

1. FACTUAL INFORMATION

All times used in this report are Singapore times. Singapore time is eight hours ahead of UTC.

1.1 History of flight

1.1.1 The Boeing 777-200 aircraft was operating a scheduled service from Brisbane, Australia to Singapore. The flight was normal until the landing at 2035 hours at the Singapore Changi Airport. The first officer (FO) was the pilot flying (PF) the aircraft.

1.1.2 The weather information broadcast by ATIS[1] 'O' at 1930 hours was rain over the airfield with braking action on Runway 02L reported as medium, wind calm and visibility of 6 km. This was updated by another ATIS 'P' at 2006 hours and the changes were highlighted by the Pilot-in-Command (PIC) to the PF during the descent. The crew intended to land with an autobrake setting of 3 and the use of full reverse thrust on a wet runway was also discussed.

1.1.3 During the descent both pilots were concerned about the weather and commented on the weather radar showing 'all red' (clouds with high water content). The crew obtained a deviation to avoid the weather.

1.1.4 On initial contact with Changi control tower, the crew were advised of rain over the airfield and strong low level windshear. The crew were also advised of medium to poor braking action reported by a preceding arrival aircraft.

1.1.5 At about 1,800 ft, Changi control tower advised the flight to continue its approach and that there was strong crosswind, but no windshear reported by the preceding arrival aircraft. At this point, the PF indicated that he would conduct an automatic landing (autoland). The PIC concurred, saying that they 'might as well do an autoland' as they 'would not be able to see the runway until a few hundred feet'.

1.1.6 Shortly after, a landing clearance was given by the tower with the surface wind reported at 140 degrees and 15 knots.

1.1.7 When the PF sighted the runway about 45 seconds later (about 600 ft above ground level) he requested to land the aircraft manually instead of using the autoland. The PIC agreed with the PF's request. The PF disengaged the autopilot at about 520 ft.

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[1] ATIS (Aerodrome Terminal Information Service) is an automatic broadcast service provided by the airport authority. The broadcast is carried out at regular intervals and each broadcast is identified by a letter of the alphabet, until the following update when a new letter is assigned.

1.1.8 In order to counter the crosswind, and maintain the desired ground track, the autopilot was maintaining a crab angle of 5 degrees into the wind. The aircraft's heading was 28 degrees and the ground track was 23 degrees.

1.1.9 After the autopilot was disengaged, the PF used the cross control technique, of applying left rudder while lowering the right wing, to counter the crosswind. The aircraft maintained the glideslope at a descent rate of about 750 ft per minute with an indicated airspeed of about 135 knots. The Vref was about 128 knots.

1.1.10 In response to changing wind conditions, the PF made frequent aileron and rudder adjustments to maintain the aircraft on the localizer of the Instrument Landing System (ILS).

1.1.11 At about 200 ft above ground, the aircraft started to deviate to the right of the localizer with the right wing low. At about 150 ft above ground, the aircraft was indicating 0.1 dot to the right of the localizer while the right wing went lower to about 2 degrees.

1.1.12 During descent from 100 to 38 ft, the PF further applied corrective actions to return the aircraft to the localizer. At about 80 ft, the right wing low became a left wing low of more than 3 degrees.

1.1.13 The aircraft moved from 0.1 dot on the right of the localizer at 26 ft to 0.1 dot left of the localizer at about 10 ft with the left wing remaining low at 2.85 degrees.

1.1.14 At one second before touchdown, the aircraft pitch attitude was 1.2 degrees nose up. At touchdown, the aircraft pitched nose up at 1.4 degrees, whereas the normal nose pitch should be about 2.5 degrees. The aircraft landed firm at 1.6 g at 0.1 dot to the left of the localizer which is about 4 m to the left of runway centreline at an indicated airspeed of 131 knots (ground speed of 148 knots) with the left wing low at 1.1 degrees. According to the crew the aircraft skidded to the left on touchdown.

1.1.15 The left hand landing gear of the aircraft departed the runway for about six seconds. From the wheel tracks in the soft ground, it was determined that the left hand landing gear had rolled about 360 m on the grass verge with the maximum displacement of about 6.2m from the runway edge (see **Appendix 1**).

1.1.16 DFDR data showed the landing gear "Not Tilt"[2] indication (indicating that the aircraft had touched down) for about four seconds. After that, the "Not Tilt" indication was changed to a "Not Valid" indication.

[2] The two main landing gears of the B777 aircraft are tilted when the aircraft is in the air. When the aircraft lands the landing gears are levelled and "not tilt" data are recorded for the gears.

1.1.17 The PIC took over the control of the aircraft with full right rudder application and brought the aircraft back on the paved surface of the runway.

1.1.18 Some antiskid system fault messages appeared on the EICAS (Engine Indication and Crew Alerting System) display during the excursion. These messages were most likely the result of damage sustained on the left hand landing gear after it departed from the paved runway surface.

1.1.19 The PIC taxied the aircraft to the assigned passenger gate after assessing it was safe to do so. The persons on board disembarked normally from the aircraft through the aerobridge.

1.2 Injuries to persons

Nil

1.3 Damage to aircraft

1.3.1 The aircraft sustained the following minor damage:

- The forward junction box mounted below the left landing gear truck beam, between the front and rear axles, was torn off.
- The aft junction box on the left landing gear was dislodged slightly from its position.
- Some conduit clamps on the landing gear shock strut were adrift.
- All six tyres on the left hand landing gear suffered rubber reversion. Tyres number 1, 2 and 5 were deflated. (See **Appendix 2**)
- Two wing-to-body fairing panels aft of the wheel well were damaged.
- One body fairing had a crack of approximately 45 cm.
- The leading edge of the left hand horizontal stabilizer had a dent of about 10 cm by 8 cm.

1.3.2 One large metal piece and other smaller fibreglass pieces (from the body fairing panels) were found on the runway. Pieces of the junction box parts were found on the grass verge.

1.4 Other damage

1.4.1 There was no damage to the runway surface. Five runway edge lights along the western side of Runway 02L between Taxiways W9 and W7 were damaged.

1.4.2 The wheel tracks on the soft ground started near the runway edge light No.132 which was about 700 m from the start of the threshold of Runway 02L and ended at runway edge light No.120. The wheel

tracks were about 360 m long and about 6.2 m at their furthest from the edge of the runway. Only the left landing gear had departed the runway.

1.5 Personnel Information

1.5.1 Pilot-in-command

Age	:	36 years (Male)
Licence	:	Airline Transport Pilot's Licence issued by the Civil Aviation Authority of Singapore
Aircraft ratings	:	B747-300, B747-400 and B777
Total flying experience	:	8558 hours
Flying experience on type	:	937 hours
Last Base Check	:	13 October 03
Last line check 777-200	:	19 September 2003
Last simulator check	:	08 July 2003
Last medical check	:	September 2003
Flight time (last 24 hours)	:	7 hours 15 minutes
Flight time (last 30 days)	:	67 hrs 13 minutes
Flight time (last 90 days)	:	176 hours 07 minutes
Rest period before flight	:	33 hours

1.5.2 First Officer

Age	:	32 years (Male)
Licence	:	Airline Transport Pilot's Licence issued by the Civil Aviation Authority of Singapore
Aircraft ratings	:	Baron Be 58, Learjet L45, A310 and B777
Total flying experience	:	1467 hours
Flying experience on type	:	688 hours
Last Base Check date	:	1 November 2003
Last line check 777-200	:	28 December 2003
Last simulator check	:	1 November 2003
Last medical check	:	August 2003
Flight time (last 24 hours)	:	07 hours 15 minutes
Flight time (last 30 days)	:	34 hours 23 minutes
Flight time (last 90 days)	:	171 hours 42 minutes
Rest period before flight	:	33 hours

1.6 Aircraft Information

1.6.1 The aircraft was serviceable and had a valid Certificate of Airworthiness.

1.6.2 The estimated landing weight of the aircraft (including about 8,300 kg of fuel) was about 179,200 kg. This weight was within the maximum allowable landing weight of 208,652 kg.

1.6.3 The aircraft has two main landing gears and a nose landing gear. Each main landing gear has three axles with two wheels mounted on each axle, making a total of six wheels per gear. The wheels are each fitted with a hydraulically operated multi-disc carbon brake unit which provides the primary means of stopping the aircraft.

1.6.4 The aircraft is equipped with two Rolls Royce Trent 800 engines. Each engine has a hydraulically operated thrust reverser. The thrust reverser system is used after aircraft touchdown to slow down the aircraft by re-directing the airflow from the engine forward, creating a reversal in thrust. The purpose of the system is to reduce the stopping distance by supplementing the aircraft brake system.

1.6.5 The aircraft is equipped with an autobrake system designed to optimise braking performance and reduce tyre wear. There are five positions, namely Settings 1 to 4 and RTO (Rejected Take-Off), on the autobrake system that provide different deceleration rates. RTO is only used during the take-off roll. Setting 1 provides the least hydraulic pressure on the brake units giving the lowest deceleration to the aircraft while Setting 4 provides the maximum hydraulic pressure. Manual input of the brake pedal will cancel the autobrake system automatically.

1.6.6 Maintenance records showed no pre-existing fault in the antiskid system or the autobrake system. DFDR data showed the autobrake pressure increased normally following touchdown.

1.7 Meteorological Information

1.7.1 The incident happened during rain. Weather information provided by the Meteorological Service Division of the Singapore National Environment Agency is incorporated in the broadcasts of Changi Airport Aerodrome Terminal Information Service (ATIS). The meteorological conditions, broadcast as ATIS 'O', at 19:30 hours were as follows:

- Light rain over airfield
- Runway surface wet
- Braking action Runway 02L reported as medium
- Wind calm
- Visibility 6 km
- Scattered clouds at 700 ft and 1,200 ft
- Temperature/dew point at 24 degrees Celsius
- QNH 1009
- Recent moderate rain
- No significant change expected

1.7.2 On initial contact with Changi control tower, the crew was advised of:

- Rain over the airfield
- Reported strong low level windshear
- Braking action reported as medium to poor

1.7.3 A minute and a half later, Changi control tower advised the crew of the following:

- Strong crosswind
- No windshear

1.7.4 From the DFDR records, from 150 ft to touchdown, the wind speed had changed rapidly from about 16.5 knots to 11 knots in 5 seconds, and 8 seconds later increased to about 20.5 knots just before touchdown. The surface wind at the time of the landing was from the southeast. This would mean a quartering tailwind (a crosswind experienced from the rear right quarter).

1.8 Aids to navigation

1.8.1 Navigation aids at Changi Airport required for aircraft operations were working normally at the time of the incident.

1.9 Communications

1.9.1 The aircraft was in contact with Flow Control of the Singapore Air Traffic Control Centre (SATCC) on 124.05 MHz and then with Arrival Control of SATCC on 119.3 MHz. It was in contact with Changi control tower on 118.6 MHz at the time of the incident.

1.9.2 The crew did not report any communication problem with the air traffic control on these frequencies.

1.10 Aerodrome information

1.10.1 Runway 02L is 4,000 m long and 60 m wide. The surface of the runway is paved with bituminous concrete and is constructed with transverse slope of 1.5 percent to permit the rapid drainage of water. The shoulders on the sides of the runway are flush with the runway, 3 m wide, and sloped at less than 2.5 percent. On both sides of the runway are flat grass areas that drain into a large drainage system about 130 m away from the edge of Runway 02L. These grass areas are sloped at 2.5 percent.

1.10.2 Singapore aerodrome operators must comply with the Singapore Manual of Aerodrome Standards as required by paragraph 67B of the Air Navigation Order.

1.10.3 The Singapore Manual of Aerodrome Standards adopts the ICAO Standards and Recommended Practices (SARPs) on aerodrome design and operations contain in Volume 1 of Annex 14 to the Chicago Convention. Hence, complying with the requirements of the Singapore Manual of Aerodrome Standards would meet ICAO SARPs of Annex 14.

1.10.4 The Singapore Manual of Aerodrome Standards recommendations for runway transverse slopes and runway shoulder slopes are stated in paragraph 7.2.1.18[3] "Transverse slopes" and paragraph 7.2.2[4] "Runway shoulders" respectively. These slopes are not to exceed 1.5 percent and 2.5 percent respectively.

1.10.5 As for the grass verge (runway strips), Singapore Manual of Aerodrome Standards' recommended slope is not to exceed 2.5 percent (paragraph 7.2.3.14[5] "Transverse slopes")

1.10.6 The day after the incident, the investigators noticed that even though it was not raining heavily, rain water accumulated at some areas on the paved runway shoulder up to about 3 m from the grass edge and about 100 mm in depth. In some places, the grass had grown higher than the level of the runway shoulder. Dead grass gathered at the edge of the runway shoulder also obstructed the drainage of rain water.

1.10.7 The airport operator carried out runway friction tests on Runway 02L-20R on 25 January 2004 (the day after the incident) between 1620 to 1725 hours. A Saab Friction Tester (SFT) equipped with a special self-wetting measuring wheel mounted behind the rear axle was used to perform the friction test. The measuring wheel was towed at a speed of 95 km per hour. Measurements of friction coefficients with 1 mm thick film of water were recorded over each

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[3] 7.2.1.18 Transverse slopes
Recommendation – To promote the most rapid drainage of water, the runway surface should, if practicable, be cambered except where a single cross fall from high to low in the direction of the wind most frequently associated with rain would ensure rapid drainage. The transverse slope should ideally be:
- 1.5 percent where the code letter is C,D, E or F; and
- 2 percent where the letter code is A or B;

but in any event should not exceed 1.5 percent or 2 percent as applicable, nor less than 1 percent except at runway or taxiway intersections where flatter slopes may be necessary. (Note: The code letter for Changi Airport Runway 02L/20R is E.)
(Corresponding reference in the ICAO Volume 1 of Annex 14: para 3.1.18)

[4] 7.2.2 Runway shoulders – Slopes on runway shoulders
7.2.2.4 Standard – The surface of the shoulder that abuts the runway should be flush with the surface of the runway and its transverse slope should not exceed 2.5 percent. (Corresponding reference in the ICAO Volume 1 of Annex 14: para 3.2.4)

[5] 7.2.3.14 Transverse slopes
Recommendation – Transverse slopes on that portion of a strip to be graded should be adequate to prevent the accumulation of water on the surface but should not exceed:
- 2.5 percent where the code number is 3 or 4; and
- 3 percent where the code number is 1 or 2;

except that to facilitate drainage the slope for the first 3 m outward from the runway, shoulder or stopway edge should be negative as measured in the direction away from the runway and may be as great as 5 percent. (Note: The code number for Changi Airport runway strips adjacent to Runway 02L/20R is 4.)
(Corresponding reference in the ICAO Volume 1 of Annex 14: para 3.3.14.)

third of the runway's length and at 3, 6 and 9 metres from the runway centreline. The average coefficients for each third of the runway (starting from the end of Runway 02L) were 0.65, 0.58 and 0.62. These values were above the maintenance friction level of 0.47 recommended in Table 14-1of the Singapore Manual of Aerodrome Standards, a level below which corrective maintenance action will have to be initiated.

1.11 Flight Recorders

1.11.1 Solid State Flight Data Recorder

1.11.1.1 The aircraft was equipped with a solid state flight data recorder (part number 980- 4700-042; serial number 08735) manufactured by Honeywell. The recorded parameters were useful to the investigation.

1.11.1.2 The landing gear data had a "Not Tilt" indication which appeared for about four seconds before it changed to the "Not Valid" indication together with the loss of other parameters related to the landing gear.

1.11.2 Solid State Cockpit Voice Recorder

1.11.2.1 An AlliedSignal solid state cockpit voice recorder (part number: 980-6022-001 and serial number 0576), with a duration of two hours was installed on the aircraft. The recorder was removed intact from the aircraft for downloading and reading out.

1.11.2.2 The outputs of the microphones of the PIC, PF, observer and the cockpit area were recorded on four separate tracks. The quality of the recording was satisfactory.

1.12 Wreckage and impact information

1.12.1 Not applicable.

1.13 Medical and pathological information

1.13.1 Not applicable.

1.14 Fire

1.14.1 There was no fire.

1.15 Survival aspects

1.15.1 This was a survivable incident.

1.16 Test and research

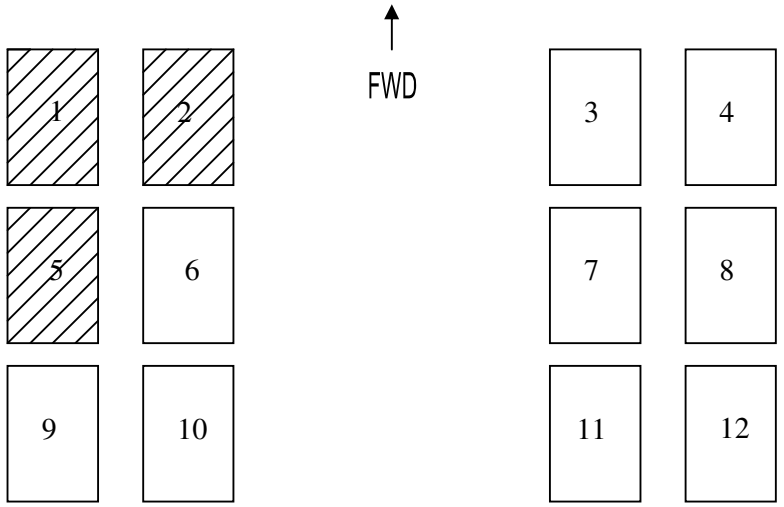
1.16.1 Nil.

1.17 Organisational and management information

1.17.1 Nil

1.18 Additional information

1.18.1 All six tyres on the left hand landing gear had rubber reversion[6], indicating reverted rubber aquaplaning had occurred. Three of the six tyres at positions 1, 2 and 5 were deflated. Below is a sketch showing the layout of the main landing gear tyres of the Boeing 777 aircraft.



Left Hand Landing Gear

Right Hand Landing Gear

Notes: Number in the box is the wheel position number.
Deflated tyres are shown shaded in the sketch above.

[6] Rubber reversion occurs when rubber of the tyre is superheated by steam caused by friction between tyre and water. This friction is most commonly brought about by aquaplaning.

1.18.2 Two tyres fitted at the No.1 and No.9 positions were sent to the tyre manufacturer, by the operator, for examination and analysis. The report from the tyre manufacturer indicated that both tyres had severe flat spotting and exposed belt plies. The damage appeared to have been initiated by reverted-rubber aquaplaning. The level of abrasion on the tyres also indicates that the tyres were blocked from rolling for some period, while in contact with the runway surface.

1.18.3 The report also indicated that the tread wear pattern of No.1 tyre showed an overload condition or partial or full loss of pressure, which resulted in the shoulder areas abrading more than the centre tread area. This tyre was apparently blocked from rolling for a greater distance than the No.9 tyre as the amount of tread rubber abrasion was much more.

1.18.4 No. 9 tyre's tread has a flat spot consistent in size with its normal load bearing, contact area. The tyre has worn in the centre rib area exposing the steel protector ply and two layers of belt ply. The wear was not sufficient to cause any loss of pressure. The slightly more central wearing (compared to the shoulders) is consistent with normal loading of that wheel.

1.18.5 There were no signs of rubber reversion or abrasion on any of the six tyres of the right hand landing gear.

1.19 Useful or effective investigation techniques

Nil

2 ANALYSIS

The investigation team's analysis covered the following areas:

a) Wind condition and crew action
b) Draining of water off the runway
c) Aquaplaning

2.1 Wind condition and crew action

2.1.1 At about 1,800 ft, after being advised by the tower of the latest weather condition over the airfield, the crew discussed the situation and decided to conduct an automatic landing as they expected the aerodrome only to be sighted at a low altitude "of a few hundred feet." At about 600 ft, they changed their decision and reverted to landing the aircraft manually. DFDR data showed that the wind direction and speed from 200 ft to touchdown were constantly changing. This resulted in the PF having to make constant adjustments of the control surfaces to maintain the ILS for approximately the last 48 seconds of flight (the rate of descent was an average of 750 ft per min). It cannot be determined whether the crew had enough time to appreciate the wind conditions experienced in the situation, i.e. quartering tailwinds, before the landing.

2.1.2 The weather conditions, as reported by the tower, were strong low level windshear, medium to poor braking action, and strong crosswinds. Although the wind direction and speed were variable, the wind conditions were within the flight envelope of the autopilot, and the autopilot system would be able to control the drift. The use of the autopilot system could have helped to lessen the workload for the crew and allowed them more time to monitor the approach and landing.

2.2 Draining of water off runway

2.2.1 Although the runway surface, runway shoulders and runway strips of Runway 02L meet the slope recommendations of the Singapore Manual of Aerodrome Standards and ICAO SARPs for the drainage of water, this incident shows that meeting these slope recommendations may not necessarily ensure that rain water will be drained away fast enough from the runway shoulder in heavy rain. The water pooling could be worse in heavier rain. The chances of aircraft aquaplaning increase with the extent of water pooling. There may be a need to review the overall design of the runway shoulder and grass area to ensure effective drainage.

2.3 **Aquaplaning**

2.3.1 The surfaces of all six tyres of the left hand landing gear had evidence of reverted rubber aquaplaning.

2.3.2 At touch down, the pitch attitude was recorded as 1.4 degrees nose up which is less than the normal pitch attitude of about 2.5 degrees. The roll attitude was left wing low at about 1.1 degrees and 4 metres left of the centreline. The aircraft was drifting sideways to the left while touching down firm at 1.6g on the left hand landing gear at a ground speed of 148 knots. The combination of all these factors could have caused an overload condition when the left hand landing gear wheels contacted the wet runway surface, and induced reverted-rubber aquaplaning.

2.3.3 Runway overruns or excursions on water-affected runways remain relatively common. The industry currently lacks a means to measure runway coefficient of friction in an actual runway contamination situation. Such measurement will provide information for crews to make better landing decision.

2.3.4 From the DFDR records, the 'Not-Tilt' indication (which indicated that the landing gear had touched the runway) lasted four seconds after which it was changed to the 'Not Valid' indication. The 'Not Valid' indication is most likely due to the junction box having been damaged after the left hand landing gear skidded off the runway.

3 CONCLUSIONS

3.1 Findings

3.1.1 The aircraft was airworthy and there were no pre-existing system deficiencies that could have contributed to the incident.

3.1.2 The crew was properly qualified and rested to operate the flight.

3.1.3 The continuously changing wind conditions near touchdown made it difficult for the PF to make accurate adjustments to land the aircraft on the centreline with the correct flare. Consequently the aircraft landed about 4 m to the left of the centreline of Runway 02L and touched down firm at 1.6 g with the left wing low.

3.1.4 The wet runway, rain, and changing wind conditions contributed to the skidding and reverted rubber aquaplaning experienced by the aircraft, which resulted in it leaving the paved surface of the runway.

3.1.5 The transverse slopes of Runway 02L, the runway shoulders and the runway strips (adjacent grass verge) of Changi Airport meet the relevant recommendations of the Singapore Manual of Aerodrome Standards and ICAO SARPs for water drainage.

3.2 Significant Factors

The following significant factors were identified:

3.2.1 The crew were aware of the changing weather conditions over the airfield. With the complications of strong crosswind and rain over the airfield, landing the aircraft with the autopilot could have lessened the workload of the crew and allowed them more time to monitor the approach and landing.

3.2.2 The aircraft was not adequately maintained on the desired ground track and aircraft attitude, owing to the changing wind conditions at low altitude.

3.2.3 Though the transverse slopes of Runway 02L have been constructed in accordance with the requirements stipulated in the Singapore Manual of Aerodrome Standards, rain water did not drain away fast enough from the shoulders of the runway.

4 SAFETY RECOMMENDATIONS

It is recommended that:

4.1 The airline enhance its crews' awareness of the hazards of aquaplaning and review its crew training on crosswind landing in heavy rain. (AAIB Recommendation R-2005-008)

4.2 The airport operator improve the drainage of water from Runway 02L shoulders to prevent water accumulation on the runway shoulders in heavy rain. (AAIB Recommendation R-2005-009)

4.3 ICAO review its Standards and Recommended Practices on runway construction to allow better drainage of water from runways in airports where heavy rain is frequently encountered. (AAIB Recommendation R-2005-010)

5 SAFETY ACTION

5.1 Arising from a previous accident investigation conducted by the AAIB, a safety recommendation was made to ICAO suggesting ICAO to encourage research that could lead to the production of equipment that can accurately measure the braking action of runways under all conditions of surface contamination.

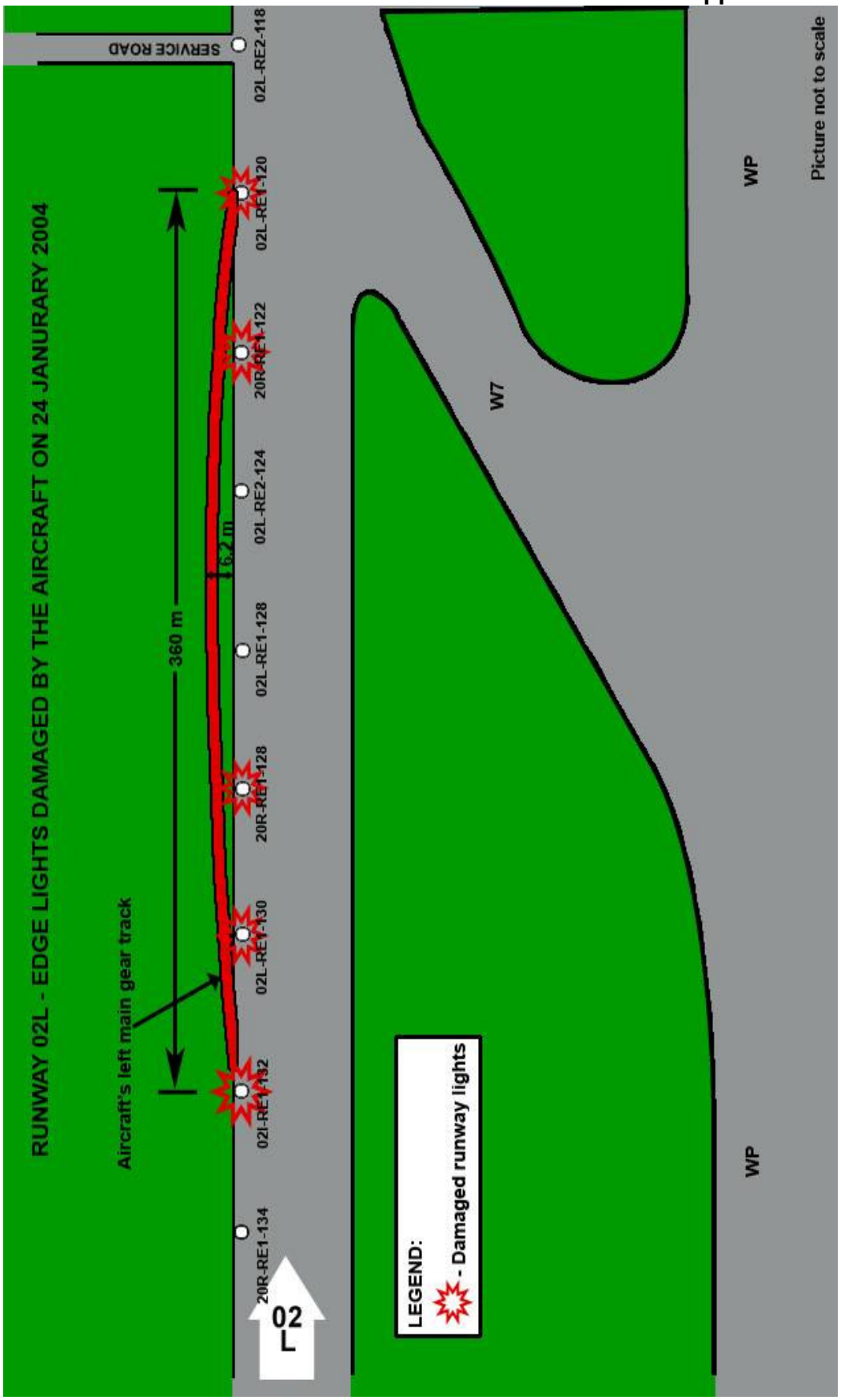
5.2 ICAO informed the AAIB in December 2004 that the development of a friction measuring device is an industry prerogative, that ICAO is currently monitoring an international effort to develop means to correlate the friction values measured by different equipment with the friction that an aircraft would experience and that ICAO will consider setting up a working group under the Aerodrome Panel to review the results and recommend future action.

6 APPENDICES

Appendix 1: Schematic of Runway 02L edge lights damaged by the aircraft

Appendix 2: Photographs showing damage to the tyres

Appendix 1


RUNWAY 02L - EDGE LIGHTS DAMAGED BY THE AIRCRAFT ON 24 JANURARY 2004
SERVICE ROAD
02L-RE2-118
02L-RE1-120
20R-RE1-122
02L-RE2-124
02L-RE1-128
20R-RE1-128
02L-RE1-130
02I-RE1-132
20R-RE1-134
360 m
6.2 m
Aircraft's left main gear track
02 L
LEGEND:
- Damaged runway lights
W7
WP
WP
Picture not to scale

Appendix 2

PHOTOGRAPHS SHOWING DAMAGE TO THE TYRES

Tyre No. 1

Tyre No. 2

Tyre No. 5

Tyre No. 6

Tyre No. 9

Tyre No. 10