Papua New Guinea

Runway overrun
Misima Airport, Papua New Guinea
31August 2010
P2-TAA
Cessna Aircraft Company Citation C550

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DOCUMENT RETRIEVAL INFORMATION

Report No.
AE-2010-068

Publication title

Runway overrun – Misima, Papua New Guinea – 31 August 2010 - P2-TAA, Cessna Aircraft Company Citation C550

Prepared by

Accident Investigation Commission of Papua New Guinea

Acknowledgements

Figure 1: Courtesy of Google maps
Figure 3: Satellite chart provided by the Australian Bureau of Meteorology
Figure 5: Provided by Jeppesen

Abstract

On 31 August 2010, a Cessna Aircraft Company Citation 550 aircraft, registered P2-TAA, with two pilots and three passengers on board, was being operated on a charter flight from Port Moresby to Misima Island, Papua New Guinea (PNG).

At about 1615, the aircraft landed on runway 26 at Misima. The aircraft aquaplaned and the crew attempted to discontinue the landing and go around from the runway. The aircraft overran runway 26 and impacted terrain. The aircraft was destroyed by a post-impact, fuel-fed fire. There was one survivor.

Prior to the accident, there had been heavy rain and low cloud at Misima that left standing water on the runway. Witness reports indicated an easterly wind at about 15 kts at the time. The investigation concluded that the accident was probably the result of the pilot in command's decision to continue the approach and landing with a tailwind that resulted in a touchdown point that was further into the runway and an increased groundspeed at touchdown, and in conditions that were conducive to aquaplaning.

The investigation identified a number of factors that led to an increased safety risk. These factors related to the crew of the aircraft, the conduct of the flight, the weather conditions affecting the flight, the condition of the runway and the aircraft documentation. A number of those factors had the potential to adversely affect the safety of future aviation operations.

As a result of the investigation, the Accident Investigation Commission of PNG identified a number of safety issues that are being addressed by the respective parties. The accident serves as a timely reminder for pilots to ensure that their aircraft's performance is adequate for the conditions and to nominate the latest safe point at which to abort a landing in adverse conditions.

AIC CHAIRMAN'S SUMMARY

Sequence of events

On 31 August 2010, a Cessna Aircraft Company (Cessna) Citation 550, registration P2-TAA, was conducting a charter flight from Jackson's International Airport, Port Moresby, National Capital District, Papua New Guinea (PNG), to Bwagaoia Aerodrome, Misima Island, Milne Bay Province, PNG (Misima). There were two pilots and three passengers on board for the flight.

The approach and landing was undertaken during a heavy rain storm over Bwagaoia Aerodrome at the time, which resulted in standing water on the runway. This water, combined with the aircraft's speed caused the aircraft to aquaplane. There was also a tailwind, which contributed the aircraft to landing further along the runway than normal.

The pilot in command (PIC) initiated a baulked landing procedure. The aircraft was not able to gain flying speed by the end of the runway and did not climb. The aircraft descended into terrain 100 m beyond the end of the runway.

The aircraft impacted terrain at the end of runway 26 at 1615:30 PNG local time and the aircraft was destroyed by a post-impact, fuel-fed fire. The copilot was the only survivor. Other persons who came to assist were unable to rescue the remaining occupants because of fire and explosions in the aircraft.

The on-site evidence and reports from the surviving copilot indicated that the aircraft was serviceable and producing significant power at the time of impact.

Further investigation found that the same aircraft and PIC were involved in a previous landing overrun at Misima Island in February 2009.

Conclusion

The investigation concluded that given the prevailing conditions, the runway was not suitable for the operation and found a number of contributing safety factors relating to the crew of the aircraft and the weather conditions that affected the aircraft's braking performance. In addition, the investigation determined that, after a previous similar incident, the operator did not take effective steps to prevent a reoccurrence.

LIST OF ACROYNOMS USED IN THIS REPORT

AATA	Australian Administrative Appeals Tribunal
AIC	Accident investigation Commission of PNG
AMSL	Above mean sea level
AOC	Air operators certificate
ATC	Air traffic control
ATSB	Australian Transport Safety Bureau
BoM	Australian Bureau of Meteorology
CAA PNG	Civil Aviation Authority of Papua New Guinea
CASA PNG	Civil Aviation Safety Authority of Papua New Guinea
CEO	Chief executive officer
CRM	Crew resource management
CVR	Cockpit voice recorder
FAAOC	Foreign aircraft Air Operator’s Certificate
FAR	United States Federal Aviation Regulation
FDR	Flight data recorder
GPS	Global Positioning System
HF	High frequency
HRS	Time expressed in hours
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
IIC	Investigator in charge
kts	Knots
LAT	Latitude
LONG	Longitude
MR	Maintenance release
NDB	Non-directional beacon
NM	Nautical mile
NZ	New Zealand
P2	PNG aircraft identification
PIC	Pilot in command
PF	Pilot flying
PNF	Pilot not flying
PNG	Independent state of Papua New Guinea
POB	Persons on board
QNH	Aircraft altimeter sub scale barometric pressure setting
QAS	Quality assurance system
SMS	Safety Management System

TAA	Aircraft registration and call sign
TAF	Aerodrome forecast
TEM	Threat and error management
VHF	Very high frequency

INTRODUCTION

The Accident Investigation Commission (AIC) is an independent Government statutory agency. The AIC is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The AIC's function is to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future, rather than to ascribe blame to any person.

The AIC performs its functions by making inquiries and undertaking investigations, preparing and publishing findings and recommendations, including any recommendations for changes or improvements that the AIC considers will ensure avoidance of accidents and incidents in the future.

1 FACTUAL INFORMATION

On Tuesday 31 August 2010, the Accident Investigation Commission (AIC) was notified of an accident that had occurred at Bwagaoia Aerodrome, Misima Island, Milne Bay Province (Misima). The accident involved a Cessna Aircraft Company 550 Citation (C550) aircraft, Papua New Guinea (PNG) registration P2-TAA.

On 1 September 2010, the Government of PNG requested assistance with the conduct of the accident investigation from the Australian Government. An accredited representative from the Australian Transport Safety Bureau (ATSB) was appointed to the PNG investigation in accordance with International Civil Aviation Organization (ICAO) Annex 13 to the Convention on International Civil Aviation, Part 5.23.

1.1 HISTORY OF THE FLIGHT

1.1.1 Pre-flight

On the morning of 31 August 2010, the flight crew prepared for a return charter flight from Port Moresby to transport a marine pilot to Misima.

Consistent with the operator's policy for operations to a length-limited runway, the pilot in command (PIC) was the pilot flying for the sector. As part of the pre-flight preparations, the copilot gathered all relevant information for the flight and submitted a flight plan. The PIC prepared the aircraft for flight and checked the flight plan details and weather information prior to departure. The aircraft was fuelled at Port Moresby with sufficient fuel for the return flight.

The aircraft operator used the opportunity to carry two supernumerary passengers on the flight for training and familiarisation purposes. One passenger was a Civil Aviation Safety Authority of Papua New Guinea (CASA PNG) Flight Operations Inspector (FOI) who had been approved by CASA PNG to undertake endorsement training on the aircraft. Prior to commencing this training, the FOI was keen to become familiar with the operation of the aircraft and its systems. The other passenger was a paramedic who crewed the aircraft when it was used for emergency medical evacuations. The paramedic had recently moved to PNG and was also on board the flight to familiarise himself with PNG operations.

While taxiing for takeoff at Port Moresby, the crew received updated information on the weather at Misima. That included that the weather had deteriorated, and that heavy showers were now forecast (see section 1.7 *Meteorological information*).

The flight departed Port Moresby at about 1500[1] and cruised to Misima at flight level[2] 330.

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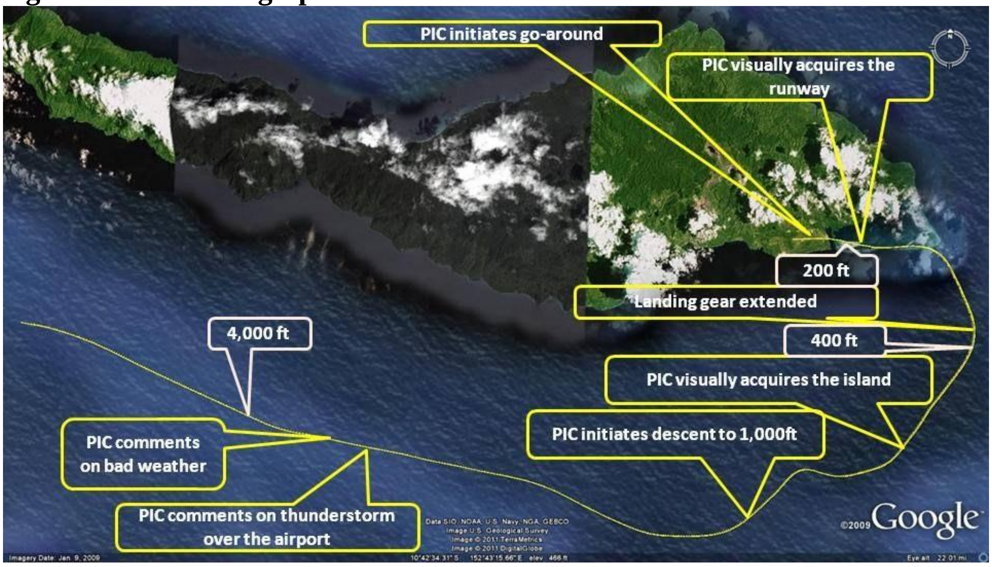
[1] Papua New Guinea local time was Coordinated Universal Time (UTC) + 10 hours.

[2] At altitudes above 20,000 ft in PNG, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 330 equates to 33,000 ft.

1.1.2 Descent and approach

According to the copilot, the information contained in the PIC's descent and approach briefing was routine in nature. Prior to the top of descent, the PIC indicated his intention to conduct a Global Positioning System (GPS) arrival until obtaining visual reference and then to conduct a visual approach (Figure 1). The copilot reported that there was no discussion about decision heights in case of a missed approach, or of runway decision points in the case of a baulked landing.[3] There was also no briefing about contingency planning in case of encountering instrument meteorological conditions during the visual approach.

Figure 1: Aircraft flightpath at Misima Island



The copilot reported that during the descent and approach to land, the PIC was constantly manoeuvring the aircraft to remain clear of cloud and rain. The PIC was reported to have indicated adverse weather on the weather radar during that time.

The copilot recalled that Misima was initially obscured by cloud during the approach and that, as the aircraft descended, Misima Island came into view. Because of the cloud and rain over the approach to runway 08[4], the only approach available at the time was for runway 26.

At 1604, the copilot sighted the sea. The PIC started to slow the aircraft and extended the flaps. At 1606, when the aircraft was about 3 to 4 NM (6 to 7 km) south of the runway, the aircraft passed through 4,000 ft. Recorded information showed that at 1608, the PIC could see a thunderstorm over the aerodrome.

The copilot responded to instructions from the PIC as they were provided, instead of following the pre-arranged multi crew duties. In that context, the copilot was instructed to only report the airspeed and any visual reference with the sea on a regular basis, and to do nothing else. The PIC reminded or reinforced this

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3 A baulked landing is a landing that has been discontinued in the final stages of an approach to land.

4 Runways are numbered based on the magnetic heading of the runway.

instruction to the copilot on five separate occasions while the aircraft was in the circuit area.

At 1610, the PIC commanded the copilot to extend the flaps to the next stage but the copilot cautioned that the scheduled flap speed was about to be exceeded. Recorded data showed that the PIC rebuked the copilot and directed the flaps to be selected down no matter what the speed. Soon after, the aircraft passed through 1,000 ft.

At 1612, a number of small islands came into view under the final approach to runway 26 and the PIC descended the aircraft to 500 ft. In order to remain clear of cloud, the PIC continued the descent to 400 ft.[5] At about this time the PIC extended the landing gear and, using the small islands on the approach path for guidance, aligned the aircraft with the runway. The copilot later reported that the runway was not visible at that stage due to the cloud and rain.

At 1614:26, the aircraft descended through 300 ft. Four seconds later the PIC stated that he was unable to see the runway. At 1614:45, the crew visually acquired the threshold of runway 26. The copilot recalled that the PIC visually manoeuvred the aircraft to remain clear of cloud and rain from that position.

A witness at the township directly under the runway 26 approach path recalled seeing the aircraft through the rain. He commented that aircraft landing on runway 26 usually flew directly overhead his location. In this case, however, the aircraft was described as being low, to the side of the extended runway centreline and banking to manoeuvre toward the runway centreline.

The PIC completed the landing checklist without the copilot’s assistance. The copilot reported that, during the approach, he did not look at the windsocks and that the crew did not discuss the wind direction. However, he noted that the sea was calm. Several witnesses on the ground reported that the wind speed in the area of the runway was at least 15 kts from the east.

At 1615:00, the PIC told the copilot that the runway would be wet on landing and that the PIC would operate the speed brakes.

1.1.3 Touchdown sequence

The calculated Vref[6] airspeed for the approach was 106 kts and the flight data recorder (FDR) information indicated that the aircraft flew over the runway threshold at about that speed. At 16:15:14, about 30 seconds after the PIC visually acquired the runway, the aircraft touched down 450 m beyond the runway threshold. As the reported tailwind was about 15 kts, the groundspeed at touchdown would have been about 120 kts.

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5 PNG Civil Aviation regulations require pilots not to descend below 1,000 ft above any congested area of a city, town or settlement or open air assemblies, or below 500 ft in other areas except in stipulated circumstances. Those circumstances include during takeoff or landing.

6 Vref refers to the correct approach speed in the landing configuration.

The copilot stated that he deployed the speed brakes and that the braking action was less than he expected. The witnesses at the terminal saw water spray coming from the tyres. Later examination of the runway showed markings that were consistent with the aircraft aquaplaning (see subsequent discussion at sections 1.12 and 18.2).[7]

At 1615:23, the aircraft's speed had reduced to about 75 kts. The PIC announced 'going round', and the crew initiated a baulked landing. The copilot reported that the aircraft had just passed the terminal building, which was about 340 m from the far end of the runway, at that time.

The copilot stated that, at the end of the runway, the N1[8] gauges were indicating 95 to 97%. The FDR showed an airspeed of 80 kts at that time. The take-off safety speed (V_2)[9] was 109 kts at the estimated landing weight. A baulked landing flown at 109 kts would, if sufficient runway remained, have ensured that the aircraft attained 35 ft above the end of the runway.

The recorded information showed that at 1615:30, the aircraft impacted terrain beyond the end of the runway. The aircraft impacted trees about 100 m from the end of the runway, which substantially damaged the aircraft and initiated a fire.

The copilot reported that, after the aircraft came to rest, he did not observe any movement from the other aircraft occupants. Because the cabin exits were blocked, he exited the aircraft unassisted through a hole in the PIC's windscreen. Shortly after, the fuel-fed, post-impact fire worsened and destroyed the aircraft wreckage.

About 5 minutes after the accident, a number of islanders who had arrived at the scene transported the copilot, the sole survivor, to the local hospital.

1.2 INJURIES TO PERSONS

Injuries	Crew	Passengers	Others	Total
Fatal	1	3	0	4
Serious	1	0	0	1
Minor/None	0	0	0	0
TOTAL	2	3	0	5

7 Aquaplaning refers to a condition where, because of a combination the aircraft's speed and standing water on the runway surface, the aircraft's tyres are unable to contact the runway surface. Aircraft steering and braking performance as adversely affected as a result.

8 Rotational speed of the low pressure compressor in a turbine engine.

9 V_2 is the minimum speed at which a transport category aircraft complies with those handling criteria associated with climb, following an engine failure. It is the take-off safety speed and is normally obtained by factoring the minimum control (airborne) speed to provide a safe margin.

1.3 DAMAGE TO AIRCRAFT

The aircraft was destroyed by impact forces and a post-impact, fuel-fed fire.

1.4 OTHER DAMAGE

The impact forces and post-impact fire damaged or destroyed a number of sago palms.

1.5 PERSONNEL INFORMATION

1.5.1 Pilot in command

Qualifications and experience

The PIC had been working in PNG for a number of years, and a significant proportion of his flying experience was conducted on C550 aircraft.[10] A summary of his known qualifications and experience is in Table 1.

Table 1: PIC details

Type of licence and instrument rating	PNG Airline Transport Pilot Licence (Aeroplane) and multiengine command instrument rating
Total flying hours	14,591.5 Last identified logbook entry on 17 February 2010
Total flying hours in the last 90 days	60.1
Total flying hours in the last 30 days	7.5
Total flying hours in the last 7 days	5.0
Last instrument rating check	2 May 2010 (per operator records)
Last 6-monthly base check	2 May 2010
Last Medical certificate issued	12 May 2010

The PIC had extensive experience operating into Misima. He was the PIC and pilot flying during another runway overrun occurrence that occurred at Misima on 19 February 2009 (see section 1.18.1 titled *Previous overrun accident*).

The PIC was a check and training captain for the operator, and held approvals to carry out the following training functions:

- line training of Training Captains, Captains and First Officers
- base training of Training Captains
- training of Captains to conduct training of Captains and First Officers

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10 The investigation was unable to examine all of the PIC's logbooks and flight and duty records and consequently an accurate assessment of the pilot's experience could not be made.

- instrument flying training.

The PIC also held approvals as a PNG flight examiner to conduct:

- line checks and instrument (IFR) and visual flight rules (VFR) base checks of Check Captains, Training Captains, Captains and First Officers
- instrument flying competency checks
- aircraft type rating training and competency assessments.

In addition to the check and training role, the PIC was the operations manager, a share holder and a director of the operator's company. The operator's chief pilot stated that at times he had felt uncomfortable speaking to the PIC on operational matters and that, although the PIC was amenable to discussions, he did not take criticism well.

Other aspects

Work colleagues did not notice any medical issues or other problems that might have affected the PIC leading up to the accident. Those who had shared accommodation with the PIC reported no problems in their personal relationships with him. However, they noted that he had spent a considerable amount of his time in recent years working on legal matters relating to aviation operations in Australia.[11] They stated that although the PIC did not usually 'take work home', they felt that he was at times distant and seemed pre-occupied with other matters.

The PIC last flew on 27 August 2010. No information was available on his recent sleep history.

It was reported that the aircraft was required to conduct a medevac[12] flight after the flight to Misima. None of those interviewed indicated that there was any pressure on the PIC to complete the flight to Misima before returning to Port Moresby.

The copilot reported that the PIC seemed normal during the flight but appeared to become a 'little stressed' during the approach. He also noted that the PIC's handling of the aircraft into Misima was not as smooth as he had seen on previous flights. He observed deviations from nominated altitudes and variations in speed.

The operator reported that the PIC had completed a crew resource management (CRM) training course (see section 1.18.3 titled *Crew resource management*); however, there was no record of this training in the pilot's training files. Copilots who had flown with the PIC reported a steep trans-cockpit authority gradient during those flights. His command style could be assertive, and there was often a lack of communication regarding operational matters. They also stated that at times he would operate the aircraft as if he was conducting a single-pilot operation.

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[11] Since 1998, the operator had made a number of applications for a foreign aircraft air operator's certificate (FAAOC) to operate PNG-registered aircraft in Australian airspace. The FAAOC was granted in February 2010. The PIC had also been dealing with legal proceedings following an accident in Australia in 2005.

[12] Used to describe a medical evacuation by air.

The copilot noted that on the accident flight, the PIC assumed an even greater degree of control over the operation of the aircraft than was normal. The copilot was not involved in any operational decisions during the flight, which was a change from the way he had been trained by the PIC, and different to the way they had operated in the past. The copilot indicated that this influenced him to not voice his concern on short final when the speed was fluctuating and the visibility was limited. Instead of raising his concerns, the copilot acquiesced as he felt that there was nothing he could have said to change the PIC's decision to land.

Other C550 copilots reported that, during flights with the chief pilot, two-crew procedures were always followed and that copilots were encouraged to participate in operational decision-making. The chief pilot also noted that at times the PIC did not fully adopt two-crew procedures.

1.5.2 Copilot

The copilot completed a command multiengine instrument rating in Australia in June 2010. At the end of June 2010, he commenced employment with the operator and began his PNG licence validation. Further details on the copilot's experience and qualifications are listed in Table 2.

The copilot conducted C550 endorsement training with the operator, including the methods for assessing aircraft landing performance. That and the copilot's C550 line training were carried out by the PIC and the copilot had flown 18.2 hours with the PIC prior to the accident. Overall, he had flown to Misima six times with the PIC.

Table 2: Copilot's details

Type of licence and instrument rating	Commercial pilot licence and multiengine, two pilot instrument rating
Total flying hours	872.4
Total flying hours in the last 90 days	37.6
Total flying hours in the last 30 days	21.9
Total flying hours in the last 7 days	2.5
Total flying hours multi crew and on the C550	37.6
Initial issue instrument rating check	2 July 2010 (per operator records)
Last Medical certificate issued	3 June 2010

The copilot last flew on 25 August 2010. He reported that he had a good rest on the night before the accident, and that there were no medical or other issues affecting his performance.

The copilot stated that he had not undergone CRM training with the operator, but he had studied CRM as part of his pilot training in Australia.

1.6 AIRCRAFT INFORMATION

1.6.1 General information

The aircraft was a pressurised, twin-engine turbofan aircraft that was configured with six passenger seats and a stretcher for medevac operations (Figure 2). Basic aircraft details are summarised in Table 1.

Figure 2: P2-TAA

Table 3: Aircraft details

Manufacturer	Cessna Aircraft Company
Model	Citation 550
Serial Number	550-0145
Registration	P2-TAA
Year of manufacture	1980
Certificate of airworthiness	Issued 15 Sept 1999
Certificate of registration	Issued 15 Sept 1999
Maintenance Release	Valid to hours/date: 14,365 hours or 23 June 2011
Total airframe hours	14,268.1 flight hours before the accident flight

1.6.2 Braking systems

The aircraft was equipped with main wheelbrakes and speed brakes for deceleration when landing. The aircraft was not fitted with thrust reversers or a drag chute[13], which were options on some C550 models.

[13] A drag chute is a type of parachute that is stowed in the tailcone and can be deployed by the crew to assist in stopping the aircraft.

Wheelbrakes

The main landing gear wheels were equipped with hydraulically-powered, anti-skid wheelbrakes. These brakes could be operated by either pilot using foot pedals. In respect of operations to wet runways, page 2-23 of the C550 *Airplane Flight Manual* (AFM) stated that:

> To insure [sic] proper braking on water, snow and ice-covered, and all unimproved surfaces, it is necessary to apply maximum effort to the brake pedals throughout the braking run. When the system anticipates a skid and releases the applied brake pressure, any attempt by the pilot can result in an interruption of the applied brake signal and may increase stopping distance significantly.

and page 4-30 of the manual stated that:

> With precipitation cover on the runway, braking should be very judicious. If runway length permits, delay braking slightly until some aerodynamic deceleration has taken effect. Under normal braking conditions the antiskid [sic] system is very effective in preventing skids and in producing minimum stopping distances, however, on precipitation covered runway the phenomena of hydroplaning may greatly reduce the anti skid effectiveness due to the possibility of the airplane wheels not rotating up to a speed equal to the airplane ground speed. Dynamic hydroplaning may occur at speeds above 73 knots.[14]

Anti-skid protection was available at speeds above about 12 kts.

Aerodynamic braking

The aircraft's speed brake system comprised a lever in the cockpit that extended a lift spoiler from the upper surface of each wing. The speed brakes acted to reduce lift and increase aerodynamic drag, reducing the aerodynamic effectiveness of the wing at high runway speeds. This allowed for earlier weight transfer onto the mainwheels, which increased the effectiveness of the wheelbrakes.

1.6.3 Aircraft landing performance

All aircraft are required to meet certain minimum performance standards during certification and operation. The standards are defined in regulations specified by the state of registration. The performance standards apply to operational variables such as take-off and landing distances, climb gradients and stall speeds, and include performance requirements that determine aircraft landing criteria.

The PNG Civil Aviation Regulations (PNG CAR) allowed aircraft that had been granted certification under the US Federal Aviation Regulations (FARs) and/or the European Joint Aviation Regulations (JARs) to be operated on the PNG register. The C550 aircraft type was certified under the FARs and operated under Part 125 of the PNG CAR.

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14 Aquaplane speed calculation is approximate and may vary depending on the formula used to calculate the aquaplaning speed.

The aircraft manufacturer provided an AFM and operating manual to assist pilots determine a number of operational factors, including the take-off and landing weight and distance requirements affecting a flight. The introduction to Section V of the AFM titled *Supplements* stated that:

> The supplements in this section contain amended operating limits, operating procedures, performance data and other necessary information for airplanes conducting special operations and for airplanes equipped with specific options. Operators should refer to each supplement to ensure that all limitations and procedures appropriate for their airplane are observed.

The supplements that were relevant to this accident included:

- Supplement 17 *Gravel runway operations*
- Supplement 36 *Restricted category operation*
- Supplement 37 *Operation in temperatures to ISA + 35*.[15]

A number of printing errors were identified in these supplements and a number of supporting charts had been omitted or placed in the wrong field. This problem was first identified in 2005/6 and was linked by the manufacturer to an upgrade of the flight manual software, which resulted in a fault with some of the supporting images. In response, the manufacturer undertook to review the manual and correct any defective images. However, due to internal manufacturer restructuring, this had not been carried out on the C550 AFM at the time of the accident.

In order to determine the aircraft’s estimated landing distance at Misima based on the flight manual data, a number of operational factors and conditions were established for the flight. These factors and conditions included:

- Temperature: 25 °C.
- Estimated landing weight: 11,890 lbs (5,380 kg).
- Indicated airspeed: Vref (105 kts).
- Wind component: tailwind in excess of 10 kts.
- Runway conditions: in terms of surface water, a contaminated runway was defined by International Civil Aviation Organization circular Cir 329 AN/191 titled *Runway Surface Condition Assessment, Measurement and Reporting* as more than 25% of the surface covered by water that was more than 3mm deep.
- Runway surface: gravel.

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[15] ISA refers to meteorological conditions in an ‘International Standard Atmosphere’. ISA conditions provide standard temperatures and pressures at specified altitudes and are used as a datum for providing aircraft performance data.

As the flight manual did not have a specific chart for calculating the landing distance in the conditions at Misima, the investigation consulted the aircraft manufacturer's aircraft performance office[16] for advice on the application of the available charts to the conditions on the day. The manufacturer advised that the landing distance required should be calculated in the following sequence:

- determine the estimated landing distance on a hard surface for the applicable tailwind (10 kts)
- correct the estimated landing distance for the runway conditions (contaminated)
- further correct that distance for the runway surface (gravel).

The estimated landing distance assumed that the aircraft crossed the threshold at Vref and a height of 50 ft, with the engine at idle before touching down 256 m beyond the runway threshold. On the occurrence flight, the aircraft touched down 450 m from the runway threshold.

The landing distance estimated from the manufacturer's performance data did not include any safety factors that were required under Parts 125.221 and 125.223 of the PNG CAR (see Appendix A). However, operators were required to ensure the application of these safety factors to determine the required runway length for a specific flight. This included, when calculating an aircraft's maximum landing weight, the need to take account of 150% of any reported tailwind component.

Table 4 provides the calculations of the estimated landing distance (based on the manufacturer's performance data) and the required runway length (including the PNG CAR-required safety factors). As indicated in this table, the estimated landing distance for the prevailing conditions was 2,622 m.

Table 4: PNG CAR-derived landing distances and required runway lengths in various conditions (effect of the prevailing conditions in bold)

Conditions	Estimated landing distance	Required runway length
No tailwind, dry runway, hard surface	2,250 ft (686 m)	3,214 ft (980 m)
No tailwind, dry runway, gravel surface	2,750 ft (838 m)	3,928 ft (1,197 m)
No tailwind, wet runway, gravel surface	4,850 ft (1,478 m)	6,928 ft (2,112 m)
No tailwind, wet runway, hard surface	5,450 ft (1,660 m)	8,947 ft (2,727 m)
10 kts tailwind, wet runway, hard surface	6,049 ft (1,843 m)	9,937 ft (9,937 m)
10 kts tailwind, wet runway, gravel surface	6,450 ft (1,966 m)	9,214 ft (2,809 m)
10 kts tailwind, wet runway, gravel surface	**8,650 ft (2,622 m)**	**9,937 ft (3,029 m)**

16 The performance data provided in the flight manual used results from the manufacturer's flight tests and reflected minimum landing distances required with no safety margin added.

1.6.4 Airworthiness and maintenance

The aircraft was maintained in accordance with the aircraft manufacturer's system of maintenance. The aircraft's maintenance release could not be located and was most likely destroyed by the post-impact fire. However, a copy of the maintenance release that was held by the operator showed that it was current at the time of the accident.

The aircraft had a current Certificate of Airworthiness and a Certificate of Registration. No maintenance anomalies were identified during the review of the available maintenance documentation.

The engine overhaul manual required a slam acceleration time check after an overhaul or replacement of certain engine components. This check confirmed that an engine being tested spooled up from ground idle to maximum power within about 5 seconds.

The copilot stated that there were no mechanical problems with the aircraft prior to the accident.

1.6.5 Weight and balance information

The aircraft was re-weighed on 1 May 2010. The aircraft's estimated landing weight of about 5,380 kg and the estimated centre of gravity were both within limits.

1.6.6 Emergency locator transmitter

The aircraft was fitted with an Artex C406 emergency locator transmitter (ELT), which was destroyed by the post-impact fire. There was no indication that the ELT activated at impact.

1.7 METEOROLOGICAL INFORMATION

1.7.1 General weather conditions at Misima

Misima Island is in the tropics and its weather patterns are influenced by the Inter Tropical Convergence Zone and the South Pacific Convergence Zone. Typical weather patterns include high rainfall, frequent afternoon/evening showers and thunderstorms.

1.7.2 Weather forecasts and reports

The Aerodrome Forecast (TAF)[17] for Misima that was issued at 0945 was valid for the aircraft's estimated time of arrival. The forecast indicated that the wind would

17 Aerodrome Forecasts are a statement of meteorological conditions expected for a specific period of time, in the airspace within a radius of 5 NM (9 km) of the aerodrome.

be 110 °(T) at 20 kts gusting to 31 kts, with showers and rain, Scattered[18] cloud with a base of 1,800 ft, Scattered cloud with a base of 4,000 ft, Broken cloud with a base of 14,000 ft, and visibility in excess of 10 km. It also stated that there would be intermittent periods of up to 30 minutes when the lowest cloud was Broken at 800 ft and the visibility would reduce to 5,000 m.

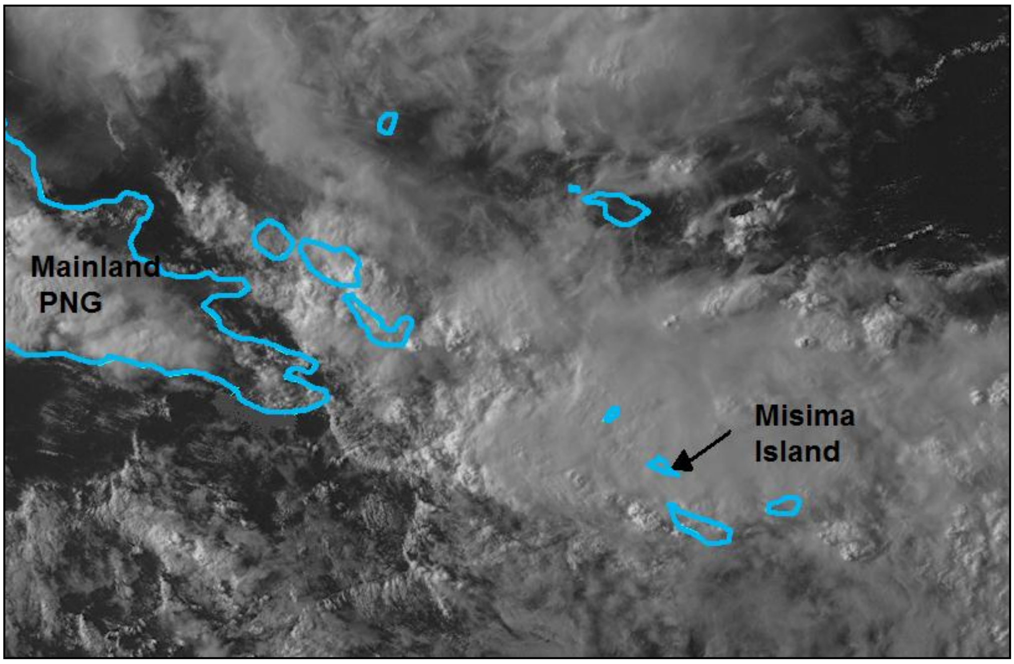
The crew received an updated weather report for Misima while taxiing at Port Moresby. The copilot stated that this report indicated a deterioration in the forecast conditions, with Broken cloud reported at several different layers, passing heavy showers, and a light and variable wind.

1.7.3 Observed weather conditions

Meteorological assessment

The Australian Bureau of Meteorology (BoM) supplied a satellite image of the region at the time of the accident, which showed cloud cover in the area of Misima Island (Figure 3). The BoM estimated the wind to have been south-easterly to easterly at 15 to 20 kts in the area of Misima Island at that time. Local wind can vary due to the influence of the surrounding topography and/or constructions, passing thunderstorms, and so on.

Figure 3: Satellite image



[18] Cloud cover is normally reported using expressions that denote the extent of the cover. The expression Few indicates that up to a quarter of the sky was covered, Scattered indicates that cloud was covering between a quarter and a half of the sky. Broken indicates that more than half to almost all the sky was covered, while Overcast means all the sky was covered.

Witness reports

Flights into Misima were met by medical staff from the Misima hospital for public health purposes. Two medical staff who witnessed the accident stated that it had been raining all day, with periods of heavy rain. They reported that, just prior to the accident, a heavy shower had passed over the aerodrome, and that it was still raining lightly when the accident occurred. The water depth at the terminal and on the runway was estimated by the medical staff to be about 50 mm and they recalled an easterly wind at about 15 kts at that time. The medical staff also reported that cloud obscured the tops of the mountains to the west of the aerodrome.

Weather station information

The Misima Island weather station was adjacent to and on the northern side of the runway and was attended by an approved weather observer (Figure 4). At 1600 on the day of the accident, the weather observer recorded the wind at the weather station as generally calm, and that the maximum recorded wind speed was 4 kts from the east. Visibility was 2,500 m with rain, and the temperature averaged 25 °C. In the 24-hour period until 1000 on the morning of the accident there was 6.2 mm of rain, and from 1000 to 1600 there was 60.6 mm of rain, with heavy showers and thunder observed.

Figure 4: Weather station and other aerodrome features

During the on-site investigation, it was noted that the weather station anemometer was recording a wind speed of 4 kts from the east. This was inconsistent with the actual conditions at the time. A portable anemometer was taken onto the runway at the point where the aircraft touched down prior to the accident and the wind speed was noted to be 15 kts from the east. The windsocks were inspected and appeared to be operating normally at that time.

An examination of the weather station revealed that, in certain wind directions, the anemometer was shielded by nearby trees and a knoll to the east. The serviceability of the anemometer was not assessed at the time of the on-site investigation. A subsequent examination was conducted and found that the measuring mechanism had malfunctioned.

The Misima weather observer stated that communications with the head office in Port Moresby were intermittent, and that he was often unable to submit weather observations to the head office.

1.7.4 PNG Civil Aviation Rules

According to PNG CARs, the minimum meteorological conditions for the visual approach included a horizontal visibility of 5,000 m and for the aircraft to remain clear of cloud and in sight of ground or water when below 3,000 ft.

1.8 AIDS TO NAVIGATION

There were no ground-based navigation aids at Misima. However, a GPS arrival procedure was published for the island.

1.9 COMMUNICATIONS

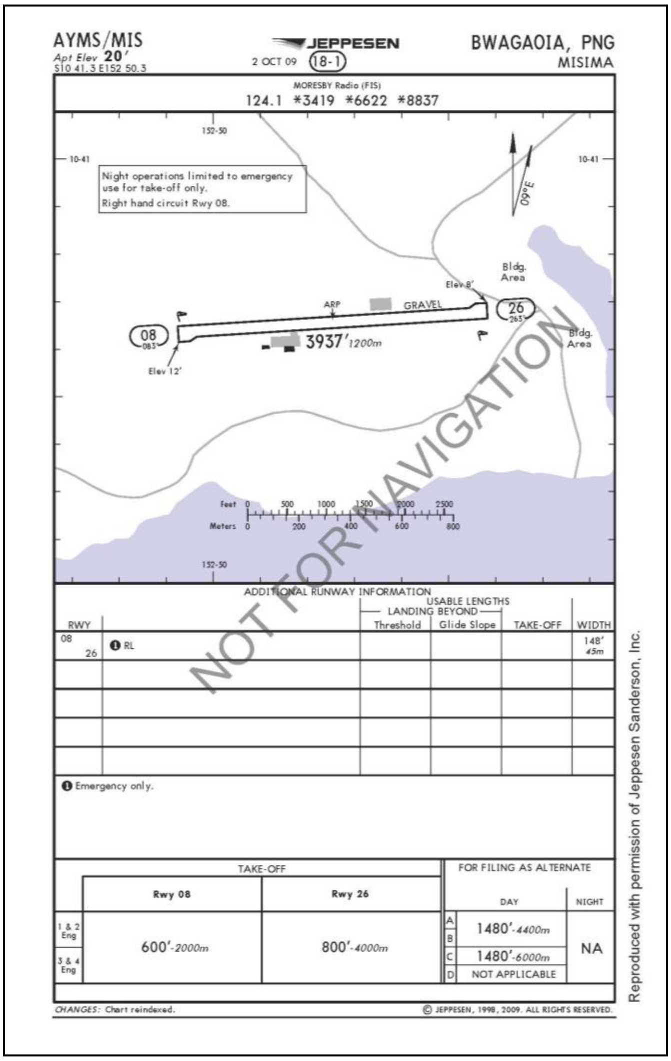
The aircraft was fitted with two very high frequency radios and one high frequency radio. There was no capability to communicate with any ground facilities at Misima.

1.10 AERODROME INFORMATION

The Bwagaoia Aerodrome (Misima) is situated at latitude 10° 41.3´S longitude 152° 50.3´E and its elevation is 20 ft. The runway was 1,200 m long and the respective runway headings 283 °(M) and 083 °(M). The Milne Bay Provincial Transport Authority was responsible for the maintenance of the aerodrome.

Standard flight documentation for Misima included an airport runway chart. The chart indicated the length of the runway, the position of the windsocks and the type of runway surface (Figure 5).

Figure 5: Misima Island runway chart



The runway chart described the runway as having a gravel surface. The investigation determined that the surface was a combination of crushed coral aggregate, which in normal conditions could be expected to provide aircraft tyres with a high coefficient of friction (important for aircraft braking). However, fine dust and soil particles had become embedded between the pieces of coral aggregate, and in places, grass had grown to about 15 to 20 cm high. Advice from the Australian Tropical Herbarium in Cairns was '...that it was not possible [from the evidence provided] to positively identify the vegetable material on the runway but it was most likely a moss, green algal mat or a lichen.'

The drainage of any surface water from the runway surface would be affected by the embedded particulate matter and the vegetable material.

1.11 FLIGHT RECORDERS

A Loral Data Systems model A100S cockpit voice recorder (CVR) and model F1000 flight data recorder (FDR) were fitted to the aircraft. Each was recovered from the empennage section of the aircraft in a fire-damaged condition and sent to the US National Transportation Safety Board (NTSB) for download. At the request of the PNG Accident Investigation Commission (AIC) the FDR data was subsequently analysed by the ATSB.

1.11.1 CVR recording

The CVR was serviceable and contained an audio recording of the last 30 minutes of the flight. According to the quality scale developed by the NTSB, the quality of the CVR recording was assessed as 'good'.

1.11.2 FDR data

The FDR recorded six parameters, including the aircraft's: pressure altitude, indicated airspeed, magnetic heading and vertical acceleration; the flight crew's microphone keying; and the elapsed time. Of those recordings, the pressure altitude and vertical acceleration data were not usable.

In addition, the recorded indicated airspeed and magnetic heading had no standard scaling information. However, non-standard scaling was derived for the recorded airspeed using the flight crew's airspeed callouts on the CVR (to within a tolerance of ± 5 kts). Non-standard scaling for heading was able to be derived from a comparison of the recorded heading information and known runway directions from previous flights (to within a tolerance of ± 3°).

A graphical representation of the recorded FDR parameters is at Appendix B.

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 Overview of the accident site

On-site examination showed that the aircraft travelled about 40 m beyond the end of the runway before the initial contact with terrain. The aircraft yawed right as a result of that impact and the left wing was facing forward during the final moments of the impact with terrain.

More significant collisions with additional sago palms were noted about 100 m from the end of the runway and the main wreckage was located on wet, swampy ground within in a large stand of sago palms about 160 m from the end of the runway (Figure 6). The aircraft's average trajectory from overhead the end of the runway to the initial tree contact was 4° down.

Figure 6: Main wreckage

1.12.2 Wreckage inspection

The extent of the damage precluded a detailed examination of some of the aircraft's components and systems. However, there was inwards bending of the left side of the fuselage in the area of the cabin door and damage to the door itself, consistent with impact loads from the left just before the aircraft came to rest. The door was also blocked by a large tree. In contrast, little structural damage was apparent in the area of the emergency exit on the right side of the fuselage.

All of the aircraft's primary structures and flight controls were accounted for at the accident site and there was no evidence of any pre-impact structural failure. Where possible, flight control continuity was established and no pre-impact defects were identified. Figure 7 shows the extent of the damage to the aircraft.

Figure 7: Damage to the aircraft

On-site examination of the wreckage indicated that the:

- landing gear selector was in the DOWN position and the main landing gear was in the down and locked position
- flap setting indicator was in the mid-range
- anti-skid selector switch was in the ON position
- aircraft's wheels and brake pack assemblies showed no evidence of any pre-accident anomaly.

The first stage compressor blades of both engines were bent in the opposite direction to rotation (Figure 8), indicating their operation at significant power at the time of impact with the terrain. The turbine sections of each engine appeared to be in good condition with no pre-accident defects identified.

Figure 8: Right engine showing indications of rotational damage

The mainwheel tyres were burnt in areas that were exposed to the post-impact fire; however, the majority of both tyres were in good condition. Localised damage was identified on parts of the mainwheel tyres that had been protected from the fire by the swampy surface water and mud (Figure 9).

The localised damage appeared to be consistent with abrasive wear and included small, sharp gouges to each surface. This damage was consistent with contact with the rock/coral runway surface by non-rotating tyres. A number of longer gouge/scrape marks were evident on the surface of each tyre and were oriented in the circumferential direction.

The shape of each localised area of damage was consistent with the tyres' footprint. That was consistent with the wheels not rotating until about 400 m after touchdown, resulting in severe localised abrasion.

No evidence of melting or reverted rubber[19] was observed on either of the damaged tyres.

[19] The permanent deformation of rubber as a result of its being heated beyond a critical temperature, wherein the rubber loses its basic mechanical properties (such as its elasticity) and becomes sticky.

Figure 9: Abrasion damage to the left and right main landing gear tyres

1.12.3 Runway inspection

Inspection of the runway showed recent, distinctive wheel tracks of similar dimensions to the aircraft's landing gear dimensions. Other recent track marks were consistent with the main landing gear of a de Havilland Dash-8-type aircraft.[20]

The first wheel track marks indicated an initial touchdown point 450 m (1,476 ft) beyond the runway threshold (Figure 10), giving 750 m (2,460 ft) of useable runway remaining. The marks extended from the touchdown point to the start of a steep down slope, about 8 m past the gable markers at the upwind end of runway 26 (Figure 11).

[20] The Dash-8 has dual main landing wheels and the C550 has single main landing wheels.

Figure 10: Runway 26 showing the initial touchdown point

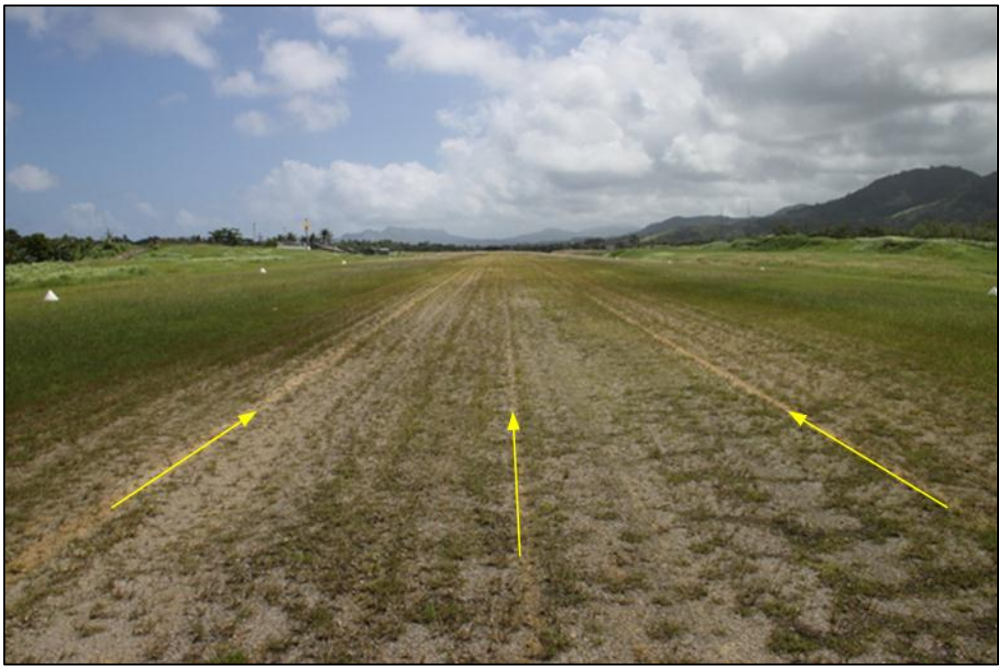
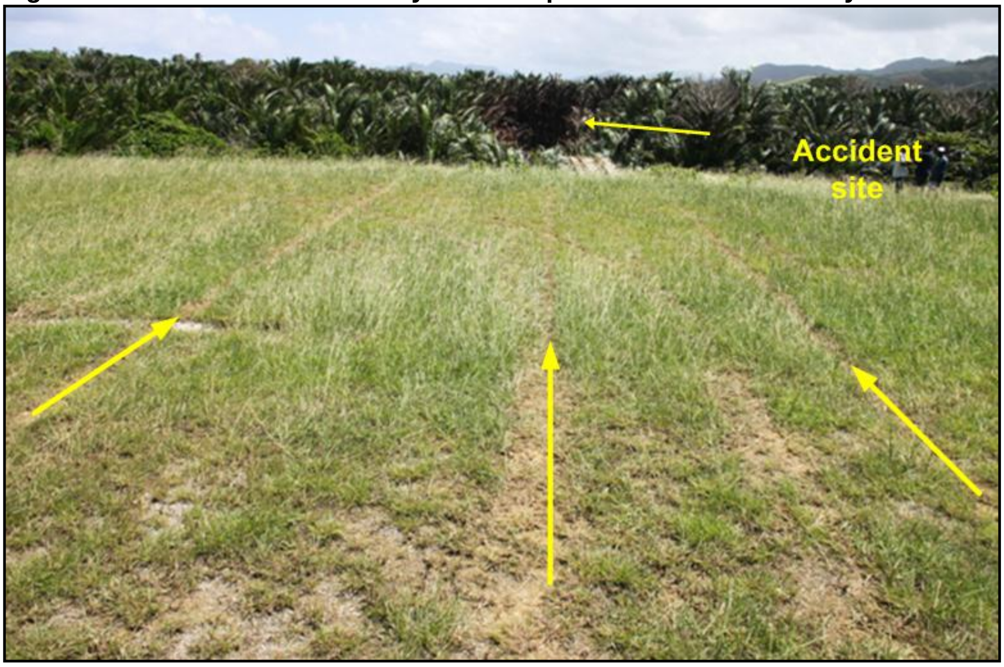


Figure 11: Wheel track marks beyond the upwind end of the runway

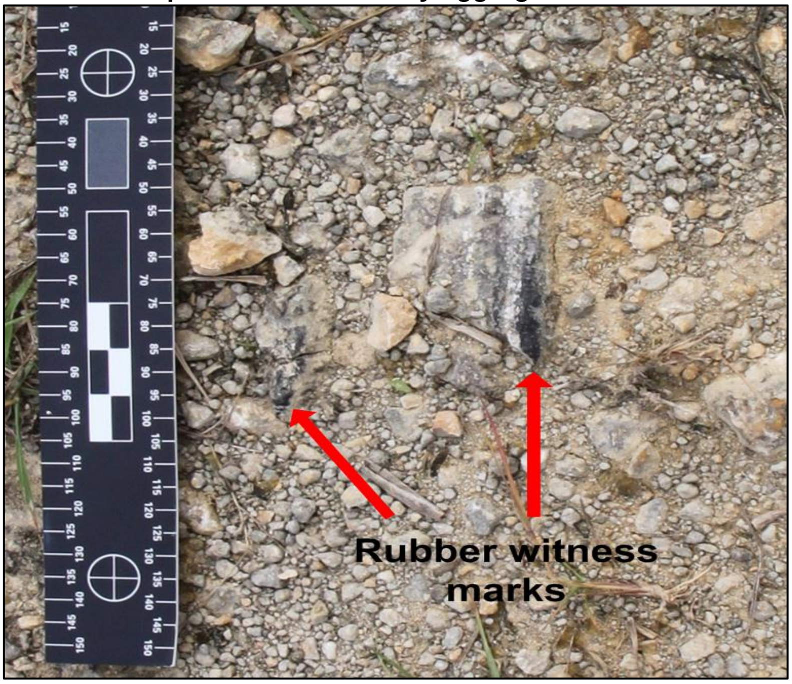


The centre of each tyre mark was virtually clear of small stones and dust for the initial 490 m. For that distance, all of the small stones and dust were deposited outside the tyre track prints, leaving only the embedded rocks and crushed coral in the soil under each tyre track. This was consistent with the tyres forcing surface water to the sides of the respective tracks (Figure 12). This scouring effect was typical of dynamic aquaplaning (see section 1.18.2 titled *Aquaplaning*).

Figure 12: Removal of the small stones and dust from the landing tyre tracks

After the scouring marks ended, the track marks indicated contact between the tyres and the runway surface, with rubber deposits and witness marks on the coral aggregate (Figure 13). The transfer marks were consistent with damage caused to a non-rotating tyre as it skidded on the runway.

Figure 13: Rubber deposits on the runway aggregate



Indications of normal wheel roll were observed after the witness marks with no evidence of scouring in between the crushed coral aggregate. That was consistent with there no longer being any aquaplaning (Figure 14). Recorded data indicated that this point coincided with the commencement of the baulked landing.

Figure 14: Indications of normal wheel roll

Measurement of the track marks at the upwind end of the runway showed that the nosewheel track marks were to the right of centre. That equated to about 10° of right yaw[21] when the aircraft left the runway.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

The PIC's autopsy was carried out in Queensland, Australia and found that there was little direct traumatic injury in consequence of the accident. In addition, the examining pathologist identified that:

> One of the coronary arteries was significantly narrowed. This was a chronic condition but was severe enough to potentially affect heart function. If [the PIC] was involved in flying the aircraft, it is not possible to exclude the possibility that this coronary narrowing could have caused abnormal heart function thereby affecting his ability to control the aircraft.

However, no sounds or other activity were recorded on the cockpit voice recording that might indicate pilot incapacitation during the approach and attempted landing. The PIC was recorded issuing directions to the copilot 2 seconds before the first sound of impact.

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21 Term used to describe the rotation of an aircraft about its vertical or normal axis.

Two of the passengers' autopsies determined that trauma was not a significant factor in their being fatally injured. The third passenger's post-mortem report indicated that there was '...very little direct traumatic injury that could be definitely attributed to the plane crash.'

The copilot sustained injuries to his left hand and elbow.

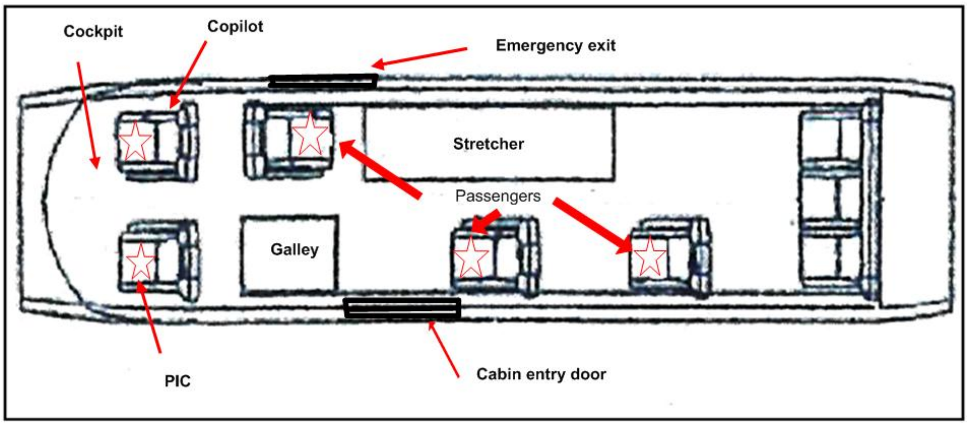
1.14 FIRE

A post-impact fuel-fed fire consumed the majority of the wreckage and was implicated in all fatal injuries. There was no evidence of a pre-impact fire.

1.15 SURVIVAL ASPECTS

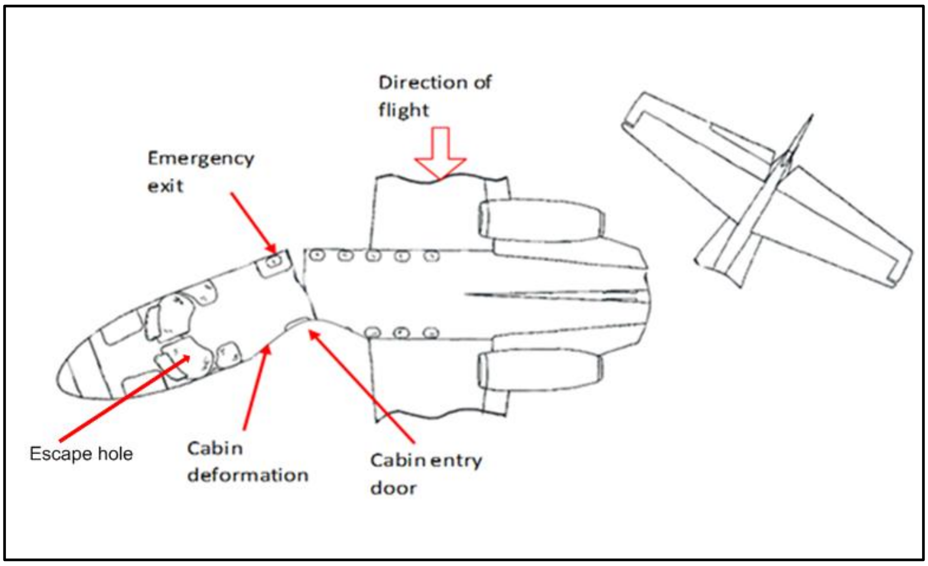
The aircraft was configured with six passenger seats, two crew seats and a stretcher. The cabin entry door was located just forward of the left wing and an emergency exit was located on the right side, adjacent to the forward right passenger's seating position. The occupant's seating positions for the flight are indicated in Figure 15.

Figure 15: Cabin layout showing occupant seating positions



The inwards movement of the left of the fuselage near the cabin door compromised the liveable cabin space (Figure 6). The deceleration forces causing that deformation would have also acted on the aircraft occupants, tending to move them towards the left side of the cabin.

Figure 16: Fuselage damage



The copilot stated that the aircraft's galley was forced to the right, blocking access to the cabin door and emergency exit. He reported escaping the aircraft by enlarging a pre-existing hole above the PIC's windscreen and then crawling out through that hole. He attempted to extricate the PIC from the aircraft but without success.

Other persons who arrived on the scene reported being unable to gain access to the cabin because of the post-impact fire. There was no firefighting equipment available that could access the accident site to assist with extinguishing the fire.

The aircraft's seats remained attached to their corresponding aircraft structures. Some seat belt components were located but the investigation was unable to ascertain if the occupants had their seat belts fastened, or if the seat belts had been intact and functioned as designed during the accident sequence.

1.16 TESTS AND RESEARCH

Not applicable to this investigation.

1.17 ORGANISATIONAL AND MANAGEMENT INFORMATION

1.17.1 Aircraft operator

The operator had carried out charter and aerial work in PNG since 1997. The primary focus of its operations was the support of medical evacuations from PNG to Australia. Other operations included ad hoc charters similar to the accident flight.

The operator used one C550 and two Cessna C208 Caravan aircraft. The only pilots who flew the C550 were the chief pilot, the PIC and the copilot. The chief pilot reported being employed in that role for 20 months prior to the accident.

1.17.2 Operations to Misima

The chief pilot stated that the operator had been flying to Misima about two to three times a week for about 15 years, and that he had completed the relevant landing performance calculations many years before. He said that the normal routine when operating into Misima was to phone a certain person on Misima prior to departure to obtain an appraisal of the weather. If the weather was unfavourable, then the flight would not depart. This person was not available on the day of the accident. The chief pilot could not recall ever not landing at Misima due to bad weather.

The chief pilot reported that flight planning was a PIC responsibility and that he was not aware of whether or how the PIC calculated the aircraft's landing performance that day, including in the case of wet, gravel, or sod/dirt runways. The chief pilot assumed that all of the relevant calculations had been completed correctly.

It was the operator's policy that PICs performed the pilot flying duties for flights into Misima and pilots reported that it was well known that the prevailing winds at Misima were easterly. They also noted that the chief pilot would normally approach Misima from the north and then do a circling approach to runway 08. In contrast, the PIC of the accident flight was reported to approach from the south for either an oblique base to runway 08 or, more normally, a circling approach to runway 26.

The chief pilot stated that personally, if the aircraft had not touched down by the second gable marker at Misima,[22] he would execute a baulked landing. There was no evidence to indicate what the PIC's decision point might have been for a baulked landing.

The chief pilot demonstrated the operator's methodology for calculating C550 landing performance for operations into Misima. He demonstrated how to incorporate allowances for the wind, runway conditions, and runway surface at Misima.

None of the operator's pilots that were interviewed during the investigation were aware of the printing errors in the *Airplane Flight Manual* Supplements.

The operator did not have any special procedures for operations using wet or contaminated runways.

A consultant who reviewed the operator's operation in March 2009 noted that that 'there is a potential for role confusion' between the chief pilot and the operations manager (PIC).

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[22] Gable markers were placed at the side of the runway strip and were spaced every 60 to 90 m.

1.18 ADDITIONAL INFORMATION

1.18.1 Previous overrun incident

Nature of the event

During the on-site investigation, an overgrown indentation was found in the overrun area of runway 26. It was not associated with the accident flight, and enquiries revealed that the aircraft had previously overrun the same runway in similar circumstances on 19 February 2009.

The 19 February 2009 flight was commanded by the same PIC as the 31 August 2010 accident but with a different copilot. The copilot of the 19 February 2009 flight recalled assessing that the aircraft was not going to stop by the end of the runway and advising the PIC to 'go around'[23] twice. This advice was not followed, and the co-pilot reported that the PIC would at times deviate from accepted multi-crew procedures.

The copilot applied maximum right brake and full right rudder in an attempt to stop the aircraft running off the end of the runway. The aircraft yawed right, and skidded sideways, coming to rest heading about 120° right of the landing direction with the left mainwheel about 4 m from the end of the runway overrun (Figure 17).

Figure 17: Left main landing gear bogged

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[23] In this context, a go-around involved abandoning the landing and applying maximum thrust to discontinue the landing and position for a new approach.

Reporting and investigation of the event

The operator was required to report the February 2009 incident to CASA PNG who advised that no such report was submitted. There were a number of disparities in the copilot's and chief pilot's recollections as to the nature and submission of a report into the incident by the copilot that day. Those discrepancies could not be reconciled.

However, the chief pilot stated that the PIC felt that the incident was a minor taxiing event. Despite the reported minor nature of the incident, the chief pilot reduced the maximum carrying capacity in the C550 to four passengers when operating to Misima.

There was no evidence of an investigation into the circumstances of the incident.

In the period 24 to 26 March 2009, an aviation safety consultant was contracted by the aircraft operator to carry out a review of the operation in relation to another matter and to provide a written report. In that report, the consultant identified that the operator's quality assurance system (QAS) was 'less than fully effective' that a safety management system (SMS) would be developed to replace the QAS. The SMS was not developed sufficiently for use in any review of the February 2009 incident.

1.18.2 Aquaplaning

The increase in landing distance on water-affected runways is primarily due to reduced braking effectiveness caused by a reduced coefficient of friction between the tyres and the runway. The reduced friction coefficient can affect deceleration and directional control. The extent of the reduction depends on the depth of the water, the affected aircraft's ground speed and the type of aquaplaning. There are three types of aquaplaning: dynamic, viscous and reverted-rubber aquaplaning.[24]

Dynamic aquaplaning

Dynamic aquaplaning occurs when the affected tyre is lifted off the runway surface by water pressure and thereafter acts like a water ski. It requires a surface water depth greater than the tyre-tread depth and sufficient ground speed to prevent the water escaping from the tyre's contact patch or footprint. Under these conditions, the tyre is wholly or partly buoyed off the runway surface by hydrodynamic force and results in a substantial loss of tyre friction. Dynamic aquaplaning can occur in depths of water as little as 3 mm.

In the case of a landing aircraft, where its wheels are initially not rotating and the depth of water is greater than the tyre-tread depth, dynamic aquaplaning can occur at speeds greater than $Vp = 7.7 \times \sqrt{Pt}$ (where Vp is the critical dynamic aquaplaning speed in knots and Pt is the tyre inflation pressure in pounds per square inch (psi)).

[24] See also pages 20 and 21 of ATSB investigation report 199904538, which is available at http://www.atsb.gov.au/publications/investigation_reports/1999/AAIR/aair199904538.aspx .

In the case of a C550 with a tyre pressure of 108 psi, the critical dynamic aquaplaning speed is about 80 kts. Above this speed, braking efficiency can be as low as 5%.

Viscous aquaplaning

Viscous aquaplaning is the most common type of aquaplaning and refers to a reduction in the friction coefficient due to a thin film of water on the runway acting as a lubricant. It can occur on damp to contaminated runways, and at speeds down to low taxi speeds. It is most severe on runways with a smooth texture.

Reverted-rubber aquaplaning

Reverted-rubber aquaplaning occurs when a wheel ‘locks up’ (or stops rotating) and is dragged across a wet surface, generating steam. The steam pressure lifts the tyre off the runway surface and heat from the steam causes the rubber to revert to its unvulcanised state, leaving a black, gummy deposit of reverted rubber on the tyre. Reverted-rubber aquaplaning also typically leaves distinctive marks on the runway, with black marks on the edges of the contact patch and a clean section in the middle where the runway has effectively been steam cleaned. This type of aquaplaning can occur at any speed above about 20 kts and results in friction levels equivalent to an icy runway.

1.18.3 Crew resource management

Overview

The principles of crew resource management (CRM) have been acknowledged as an integral part of aircraft operations.[25] CRM encompasses a wide range of knowledge, skills and attitudes including communications, situation awareness, problem solving, decision making, and teamwork; together with all the attendant sub-disciplines that each of these areas entail.

CRM can therefore be defined as a management system that is designed to make the best use of all available equipment, procedures and people to promote safety and enhance the efficiency of flight operations.

CRM does not relate so much to the technical knowledge and skills required to fly and operate an aircraft. Instead, it relates to the cognitive and interpersonal skills needed to manage the flight within an organised aviation system. In this context, cognitive skills are defined as the mental processes used for gaining and maintaining situation awareness, for solving problems and for making decisions. Interpersonal skills relate to communications and a range of behavioural activities associated with teamwork.

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25 For example, see the International Civil Aviation Organization (ICAO) (1998) *Human Factors Training Manual* (Doc 9683-AN/950).

Trans-cockpit authority gradient

Trans-cockpit authority gradient refers to the differences in the expected operational contributions by each crew member. The gradient may be influenced by a crew member's experience, authority and willingness to act as an individual or as part of a team. An inappropriate balance of these socio-psychological influences can interfere with the proper exchange of information in the cockpit and thus with the safe operation of the aircraft. A steep gradient between a dominant PIC and submissive copilot may result in a PIC not listening to the concerns of a copilot and/or the copilot being less willing to communicate important information to a PIC.

An optimum trans-cockpit authority gradient recognises the command authority of a PIC, while encouraging a copilot to contribute to the crew's decision making processes. This optimum gradient facilitates communication, enables participative leadership, establishes a team culture and enhances crew situation awareness. These concepts are part of the CRM training syllabus as outlined in the ICAO *Human Factors Training Manual.*

1.18.4 Multi-crew operation

The chief pilot reported that the C550 had always been intended as a multi-crew operation and that all pilots were expected to operate the aircraft using two-crew procedures. Because of the relatively low experience levels of the copilots, the chief pilot treated every flight like a training exercise for the copilots.

As the aircraft was operated in charter and aerial work operations, the crew were not required to be trained in CRM under PNG civil aviation regulations. However, the operator's operations manual required pilots to be trained in CRM and the chief pilot stated that the operator had a CRM manual and that all crew members had completed this training.

2 ANALYSIS

2.1 INTRODUCTION

It is apparent from the physical evidence, reports from the surviving copilot and other witnesses and recorded data that the aircraft struck trees beyond the runway while attempting a baulked landing.

The examination of the wreckage and the copilot's statement suggest that there was no pre-existing mechanical condition that could have been a factor in the accident. Similarly, the copilot's recollection of the event was consistent with the recorded data and suggested that the pilot in command's (PIC) health and physical condition were not a factor.

A number of operational and human performance issues were identified that were likely to have influenced the outcome. The following discussion examines those factors and their contribution to the accident.

2.2 AIRCRAFT PERFORMANCE

2.2.1 Landing performance

Ability to stop in the available runway

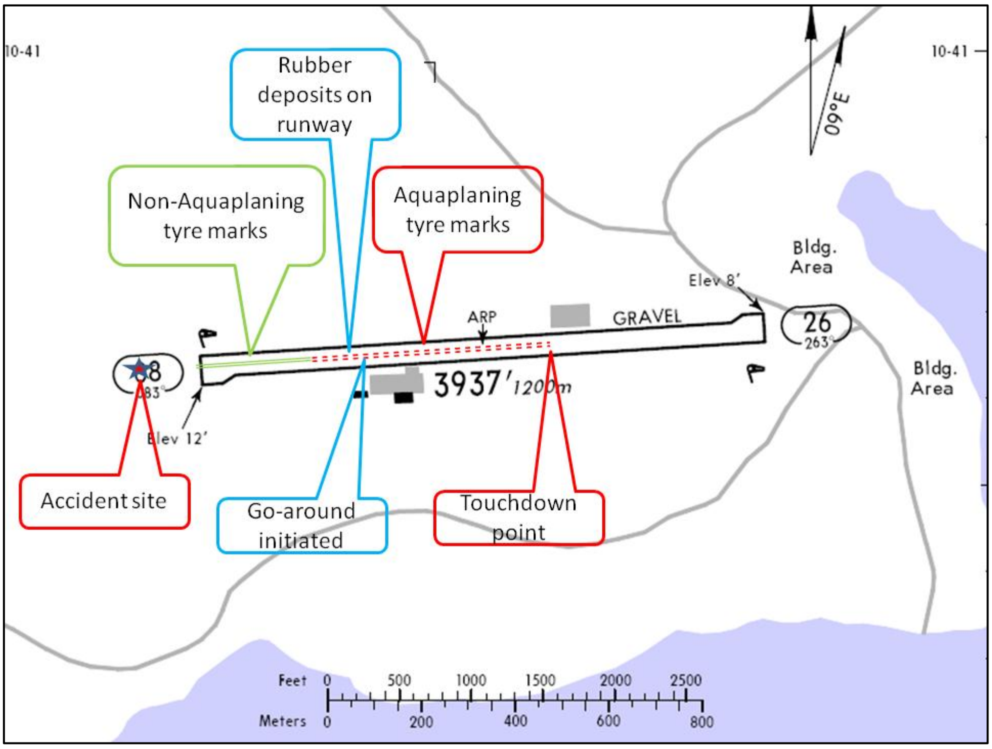
Application of the Papua New Guinea (PNG) Civil Aviation Safety Authority required landing safety factors to the aircraft manufacturer's landing performance charts and supplements showed that the only situation where the available 1,200 m of runway would have sufficed was if the aircraft touched down at the correct position, there was no tailwind and the gravel runway surface was dry. The touchdown 194 m further along the runway than assumed in those charts, on a degraded runway surface with standing water, and with a tailwind of 10 kts meant that there was no prospect that the aircraft would be able to stop on the remaining available runway.

Baulked landing

The dynamic aquaplaning that was experienced after touchdown would have severely compromised the aircraft's braking until established below its aquaplaning speed of about 80 kts, resulting in the use of additional runway to that expected. At that speed, the aircraft would have used about an additional 220 m of runway during the at-test up to 5 seconds taken for the engines to accelerate from idle to full power. With 260 m of runway remaining at that time, the remaining 40 m of runway once established at full power would have been insufficient to allow the aircraft to accelerate to 109 kts and pass over the trees at the end of the runway by at least 35 ft (Figure 18).

The nomination by the PIC of a baulked landing decision point, as routinely applied by the chief pilot, would have increased the likelihood of an early decision to discontinue the landing and, had that decision been made, have avoided the accident. Such decision points have application in all operations to length-limited runways.

Figure 18: Runway wheel track marks



2.2.2 Aircraft manufacturer's performance data

The omission or incorrect incorporation of a number of performance charts and supplements in the C550 airplane flight manual (AFM) suggested that the manufacturer's system for providing accurate information to pilots, or amending that information from time to time was unreliable. Although this problem had existed since 2008, it had not been identified by, or reported to the manufacturer. This indicated that either operators had adapted earlier charts into their own procedures, mitigating the risk associated with the inaccurate charts and supplements, or that the manufacturer's charts were not being used.

In this instance, the non-use of the manufacturer's charts and supplements meant that their inaccuracy did not contribute to the accident. Importantly however, the lack of awareness of the inaccuracies by a number of the operator's C550 pilots suggested that they had not routinely accessed or applied the charts and supplements since at least 2008.

2.3 AERODROME FACILITIES

2.3.1 Weather station anemometer and reporting

Accurate flight planning and appropriate in-flight management and, if required diversion planning and execution relies on reliable weather forecasts and reports. The weather station at Misima provided weather information to the PNG National Weather Service (NWS), which used that information to promulgate weather forecasts and observations for use by pilots.

The inaccurate indication by the anemometer at Misima of the wind speed affecting the runway increased the risk of the provision of inaccurate observations and/or forecasts to pilots. As a result, there was the potential for unintentionally inappropriate planning or in-flight decision making by affected pilots. The reported intermittent communications with the NWS head office in Port Moresby, and resulting inability of the Misima weather observer to reliably submit weather observations to the head office increased that risk.

However, in this instance the forecast that was received by the flight crew was an accurate reflection of the conditions at the time of the accident and the windsocks at the runway were reported to have preformed correctly. The investigation concluded that the inaccuracy of the anemometer was not a factor in the development of the accident.

2.3.2 Aerodrome maintenance

The decline in the aerodrome's facilities and upkeep resulted in the crushed coral runway surface becoming overgrown by vegetation, which reduced the braking coefficient of the runway surface and the ability for water to drain from the runway. This degradation in the 'gravel' runway surface was not reflected in pilot operational documentation, meaning that landing performance would not reflect that anticipated by arriving pilots.

However, the accident pilot's extensive experience of operations into Misima meant that he would have been aware of the nature of the runway surface. It might have been expected that the PIC should have taken account of the nature of runway surface in any performance planning.

2.4 FLIGHT CREW PERFORMANCE

2.4.1 Performance planning

As part of their aircraft type endorsement and recurrent training, both crew members would have been required to demonstrate competence in calculating the landing distance required using the landing data in the C550 AFM. Routine application of that knowledge during the PIC's many flights to Misima would, if carried out, have ensured continued competence in those calculations as they applied to operations at Misima.

On the day, the application of the forecast weather and runway condition to the aircraft's performance charts would have clearly shown that there was insufficient runway available for a safe landing. The action by the PIC to attempt the landing suggested that either the PIC accepted the risk of having not calculated the landing distance and runway required, that his calculations did not take account of the ambient conditions, or that there was an error in his calculations.

The likelihood that the PIC did not apply the ambient and runway conditions to the calculation of the required landing distance was consistent with the chief pilot's omission of their effect when performing the calculations for operations to Misima as part of the investigation. Moreover, the lack of knowledge amongst the operator's C550 pilots of the errors in the manufacturer's performance supplements suggested that they too had not routinely applied their requirements to the operation of the C550.

The investigation concluded that the operator's processes for calculating the landing distance required did not ensure the application of all relevant performance factors to those calculations.

2.4.2 The decision to continue the approach from final

The constant manoeuvring during the descent to remain clear of cloud and requirement for the copilot to report visual reference with the sea suggested that the PIC was aware of and attempting to satisfy the requirements for a visual approach. Indeed, the loss of sight of the runway from within the circuit area when below 300 ft would suggest that the crew should have discontinued the approach, as the conditions were below those for a visual approach. The lack of any prior consideration of the need for a go-around should the visibility decrease below 5,000 m, or of being unable to maintain clear of cloud once below 3,000 ft, increased the likelihood that the crew would continue the landing regardless of the conditions.

By continuing the approach to land from that position, the PIC significantly increased the workload leading up to the touchdown. Together with the crew's lack of awareness or consideration of the tailwind, or of its acceptance, that elevated workload increased the risk of a final approach that was faster over the ground than anticipated and that touched down further into the runway than intended. Had the crew conducted a go-around when the conditions did not allow for a visual approach, and returned the aircraft to a safe altitude, they would have been able to consider and plan other options. Given the remaining fuel on board, those options included returning to Port Moresby.

2.4.3 Crew resource management

The PIC's management of the approach and landing at Misima, including limiting the involvement of the copilot reflected the steep trans-cockpit gradient at the time, and the at times single pilot-like approach reported experienced by other copilots when flying with the PIC. This resulted in the breakdown of the operator's crew resource management (CRM) methodology. The result of that breakdown was twofold:

- The PIC significantly increased his workload during a critical phase of fight in adverse weather conditions. That included extending the landing gear and flaps and actioning the landing checklist, and the intent to action the speed brakes. This elevated workload had the potential to affect the PIC's manipulative and decision making skills.
- The copilot reverted to only reporting airspeed and any visual reference with the sea – as directed by the PIC. This was contrary to the pre-arranged multi crew duties in the operator's CRM methodology and diminished an important safety defence with the potential to have influenced the approach, the consideration of a go-around and ultimately the execution of a safe landing at Misima.

2.5 PREVIOUS INCIDENT

The previous overrun should, in a mature safety system, have resulted in the initiation of an investigation into the occurrence. It could be expected that an investigation would have provided an excellent opportunity to learn lessons from that overrun and initiate corrective safety action to reduce the risk of a recurrence. Those lessons, such as the reliable application of the manufacturer's performance charts and supplements to the operator's C550 operations, had direct relevance to the 31 August 2010 accident.

The action taken by the operator after the 19 February 2009 incident to reduce the C550 maximum landing weight was, by itself not an effective risk control. As evidenced by this repeat accident, there are tangible benefits in operators maintaining a reliable incident reporting and investigation process as an integral part of their safety system.

3 FINDINGS

From the evidence available, the following findings are made with respect to the runway overrun that occurred at Misima Island, Papua New Guinea on 31 August 2010 involving a Cessna Aircraft Company 550 Citation, registered P2-TAA. They should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 Contributing safety factors[26]

- The operator's processes for determining the aircraft's required landing distance did not appropriately consider all of the relevant performance factors. *[Minor safety issue]*[27]
- The operator's processes for learning and implementing change from the previous runway overrun incident were ineffective.
- The flight crew did not use effective crew resource management techniques to manage the approach and landing.
- The crew landed long on a runway that was too short, affected by a tailwind, had a degraded surface and was water contaminated.
- The crew did not carry out a go-around during the approach when the visibility was less than the minimum requirements for a visual approach.
- The baulked landing that was initiated too late to assure a safe takeoff.

3.2 Other safety factors[28]

- The aircraft aquaplaned during the landing roll, limiting its deceleration.
- The runway surface was described as gravel, but had degraded over time. *[Minor safety issue]*
- The weather station anemometer was giving an incorrect wind indication. *[Minor safety issue]*

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26 For the purposes of this report, a safety factor is an event or condition that increases safety risk. A contributing safety factor is one which, had it not happened or existed, then either:
- the occurrence would probably not have occurred
- the adverse consequences associated with the occurrence would probably not have occurred or been as serious
- another contributing safety factor would probably not have occurred or existed.

27 A safety issue is a safety factor with the potential to adversely affect the safety of future operations. A minor safety issue is associated with a broadly acceptable level of risk.

28 Other safety factors are those factors which increase safety risk without directly affecting the accident.

- The unreliability of the communications facilities prevented the weather observer from transmitting regular weather updates to Port Moresby. *[Minor safety issue]*
- There were a number of printing errors in the aircraft manufacturer's C550 performance and supplementary information charts. *[Minor safety issue]*

4 SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Accident Investigation Commission of Papua New Guinea (AIC PNG) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the AIC PNG prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

4.1 CIVIL AVIATION SAFETY AUTHORITY OF PAPUA NEW GUINEA

4.1.1 Runway surface

Minor safety issue

The runway surface was described as gravel, but had degraded over time.

Safety action taken/response from the Civil Aviation Safety Authority of Papua New Guinea

An inspection of the aerodrome was undertaken by the Civil Aviation Safety Authority of Papua New Guinea (CASA PNG) shortly after the accident in order to identify any pre-existing safety issues that required action before aerodrome licensing could take place. A report was prepared for the operator of the aerodrome on the runway condition. A number of recommendations were made, including that the aerodrome operator should:

- apply to CASA PNG for exemptions against the requirement to have a 60 m graded runway strip
- remove the algae/lichen material from the runway surface to the extent possible
- cut back the trees and shrubs that were close to the runway ends and infringing the approaches
- cut back the trees that were infringing the runway approaches but were further away from the runway end as the opportunity arises.

4.2 PAPUA NEW GUINEA NATIONAL WEATHER SERVICE

4.2.1 Misima wind indicators

Minor safety issue

The weather station anemometer was giving an incorrect wind indication.

Safety action taken/response from the Papua New Guinea National Weather Service

The Papua New Guinea National Weather Service (PNG NWS) has advised that one of the windsocks at Misima has been replaced. The anemometer was found to be unserviceable and has been taken out of service.

4.2.2 Communication of weather reports

Minor safety issue

The unreliability of the communications facilities prevented the weather observer from transmitting regular weather update to Port Moresby.

Safety action taken/response from the PNG NWS

The PNG NWS has advised that five automatic weather stations have been installed in PNG, one of which has been placed at Misima. Pilots will be able to access this information within a 30 NM (56) radius of the stations. At the time of writing, the Misima station had not been commissioned and no date had been advised of a possible commissioning date.

4.3 CESSNA AIRCRAFT COMPANY

4.3.1 Aircraft performance charts

Minor safety issue

There were a number of printing errors in the aircraft manufacturer's C550 performance and supplementary information charts.

Safety action taken/response from the aircraft manufacturer

The aircraft manufacturer reported that it has reviewed every page of every supplement for the Cessna 550 type aircraft Airplane Flight Manual and has taken action to ensure that the manual is complete and ready for distribution. In addition, the company flight manual group commenced reviewing a large sampling of the flight manuals for the manufacturer's other aircraft models. The manufacturer has advised that, if those manuals contain defective files, the validation process will continue until it is confirmed that no defective files remain.

APPENDIX A: PNG CIVIL AVIATION RULES – RELEVANT PART 125 REQUIREMENTS

The elements of Part 125 of the Papua New Guinea Civil Aviation Regulations that were relevant to this accident are outlined in the following quotes.

Subpart A — General 125.1 Purpose

(a) Subject to paragraph (b), this Part prescribes rules governing air operations using an aeroplane—

(1) having a seating configuration of 10 to 19 seats, excluding any required flight crew member seat, or

(2) having a payload capacity of 2200 kg or less and a MCTOW of greater than 5700 kg; or

(3) powered by a single engine for the carriage of passengers under IFR.

(b) If either the seat numbers or payload capacity of the aeroplane falls into the applicability for Part 121, then the operation shall be conducted under Part 121.

125.209 Runway surface and slope correction factors

A certificate holder shall ensure that, unless alternative performance data acceptable to the Director is available and used, the take-off distance calculated for a runway surface type under 125.207(c)(4) and the landing distance calculated under 125.223(c)(3)—

(1) Are corrected for use of other runway surface types by applying the factors in Table 1;

Part 125.221 Landing distance – dry runway

(a) A certificate holder shall ensure that, for each aeroplane it operates, the landing weight for the estimated time of landing will not exceed the landing weight specified in the aeroplane flight manual.

(b) A certificate holder shall ensure that, for each aeroplane it operates, the landing weight of the aeroplane for the estimated time of landing at the destination aerodrome and at any alternate aerodrome allows a full-stop landing from 50 feet above the threshold within 70% of the landing distance available assuming that the aeroplane is landed.

(c) When calculating the landing weight in accordance with paragraph (b), the holder of an air operator certificate shall take account of—

(1) aerodrome elevation; and

(2) ambient temperature at the aerodrome; and

(3) the type of runway surface and the runway surface condition; and

(4) the runway slope in the direction of landing; and

(5) not more than 50% of the reported headwind component or not less than 150% of the reported tailwind component.

(d) For dispatch of an aeroplane to land in accordance with paragraphs (b) and (c), it shall be assumed that the aeroplane will land on the most favourable runway taking into account—

(1) the forecast meteorological conditions; and

(2) surrounding terrain; and

(3) approach and landing aids; and

(4) obstacles within the missed approach flight path.

(e) If the holder of an air operator certificate is unable to comply with paragraph (d) for the destination aerodrome, the aeroplane may be dispatched if an alternate aerodrome is designated and available that permits compliance with paragraphs (a), (b), and (c).

Part 125.223 Landing distance –contaminated runways

A certificate holder shall ensure that, for each aeroplane it operates, when the appropriate weather reports or forecasts, or a combination of them, indicate that the runway at the estimated time of arrival of its aeroplane may be contaminated, the landing distance available is at least 115% of the landing distance required by 125.221.

125.205 General aeroplane performance

A certificate holder shall ensure that, for each aeroplane it operates—

(1) the take-off weight at the start of its take-off is not greater than the weight permitted under this Subpart for the flight to be undertaken allowing for the expected reductions in weight as the flight proceeds; and

(2) the performance data used to determine compliance with the performance requirements of this Subpart is—

(i) contained in the aeroplane flight manual; or

(ii) in the case of contaminated landing distance data, provided by the aeroplane manufacturer and acceptable to the Director.

125.209 Runway surface and slope correction factors

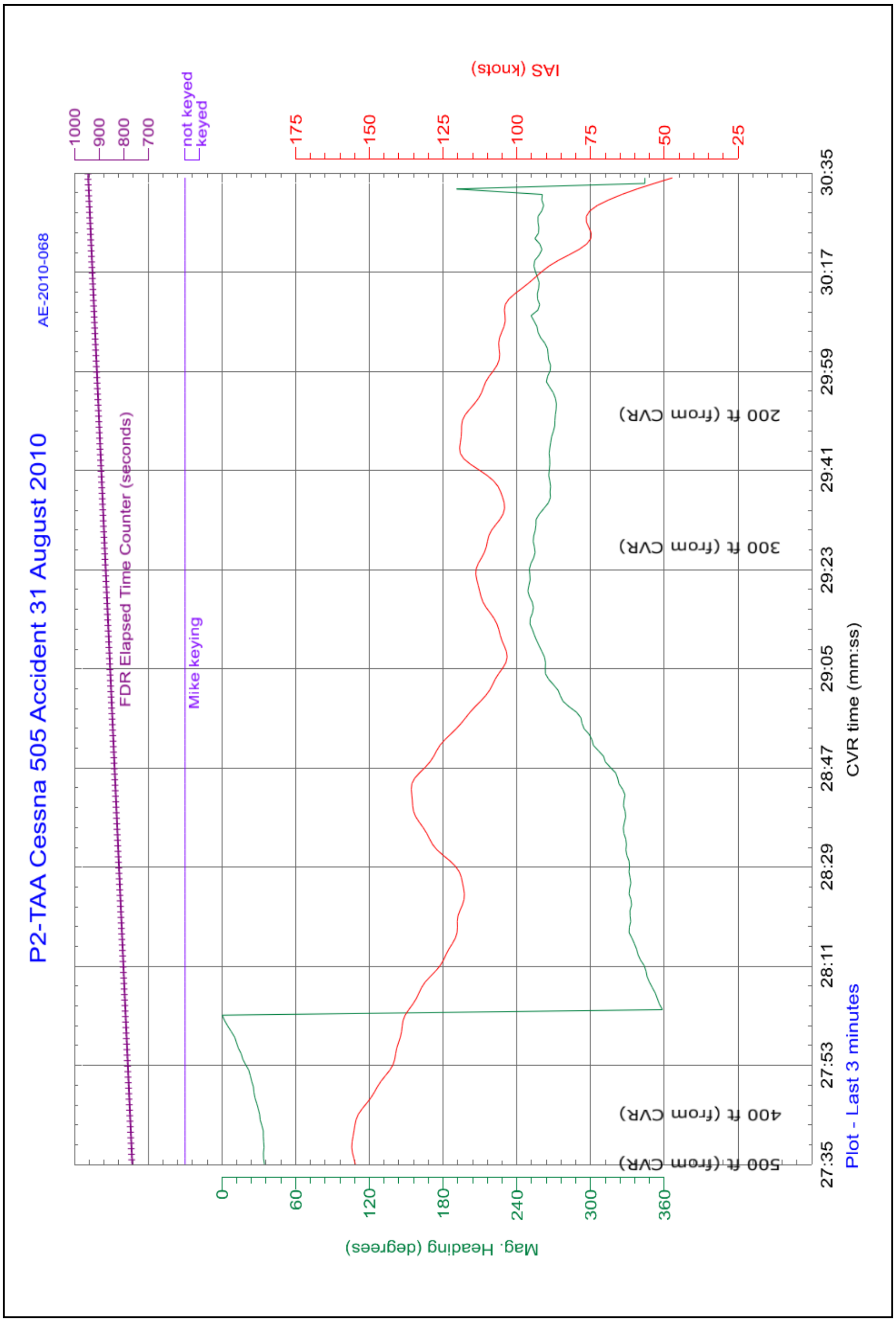
A certificate holder shall ensure that, unless alternative performance data acceptable to the Director is available and used, the take-off distance calculated for a runway surface type under 125.207(c)(4) and the landing distance calculated under 125.223(c)(3)—

(1) are corrected for use of other runway surface types by applying the factors in Table 1:

Table 1

Paved	x 1.00	x 1.00	x 1.00
Coral	x 1.00	x 1.03	x 1.05
Metal	x 1.05	x 1.06	x 1.08
Rolled earth	x 1.08	x 1.14	x 1.16
Grass	x 1.14	x 1.20	x 1.18

APPENDIX B: FLIGHT DATA RECORDER PLOT



APPENDIX C: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included the:

- copilot of the aircraft
- chief pilot
- Queensland Coroner
- Queensland Police Air Wing
- aircraft manufacturer
- Papua New Guinea National Weather Service (NWS)
- Bureau of Meteorology (Australia)
- Civil Aviation Safety Authority Papua New Guinea (CASA PNG).

References

Royal Aeronautical Society (1999) Paper by *CRM Standing Group Crew Resource Management*. UK

Hurt, H. H. Jr. (1965) *Aerodynamics for Naval Aviators,* The Office of the Chief of Naval Operations, Aviation Training Division, USA.

International Civil Aviation Organisation (2006) Document 9868 *Procedures for Air Navigation Services - Training.*

Submissions

The Accident Investigation Commission (AIC) may provide a draft report, on a confidential basis, to any person whom the AIC considers appropriate under the *Civil Aviation ACT 2000.*

A draft of this report was provided to the aircraft manufacturer, the US National Transportation Safety Board, the operator, the copilot of the aircraft, CASA PNG and the NWS.

Any submissions received will be reviewed and, where considered appropriate, the text of the report will be amended accordingly.