Australian Government

Australian Transport Safety Bureau

RESEARCH REPORT
B2004/0246

Destination Weather Assurance

Risks associated with the Australian operational rules for weather alternate minima

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

ISBN 1 921092 50 5 June 2006

This report was produced by the Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608.

Readers are advised that the ATSB investigates for the sole purpose of enhancing safety. Consequently, reports are confined to matters of safety significance and may be misleading if used for any other purpose.

CONTENTS

EXECUTIVE SUMMARY ... vii

ABBREVIATIONS ... ix

1 INTRODUCTION ... 1

2 ENGINEERED RELIABILITY ... 3

3 METHOD ... 5

3.1 Aircraft types ... 5
3.2 Types of limiting weather phenomena ... 5
3.2.1 Visibility ... 6
3.2.2 Cloud base ... 6
3.2.3 Crosswind and downwind ... 6
3.2.4 Thunderstorms ... 6
3.3 Destination weather alternate assessment ... 7
3.4 Data sources ... 7
3.5 Data variables ... 8
3.5.1 Time between forecast issue and landing ... 8
3.5.2 TAF and TTF ... 9
3.6 Comparisons ... 9

4 BELOW LANDING MINIMA EVENTS ... 11

4.1 Frequency of ‘below landing minima’ events ... 11
4.2 Types of limiting phenomena that make an event ‘below landing minima’ ... 12
4.3 Similar information ... 13

5 POTENTIALLY UNSAFE EVENTS ... 15

5.1 Forecast prediction accuracy for below landing minima events ... 15
5.2 Forecast prediction accuracy for below landing minima events, compared with all weather events ... 17

6 COMPARISON OF ACCURACY OF TERMINAL AERODROME FORECASTS WITH TREND TYPE FORECASTS ... 19

7 OPERATIONAL DEFENCES ... 21

7.1 En-route defences ... 21

8 RATES OF UNFORECAST WEATHER-RELATED SAFETY OCCURRENCES THAT WERE REPORTED TO THE ATSB ... 23

9 ALTERNATIVE METHODOLOGIES ... 25

9.1 Different criteria for weather alternate requirements ... 25
9.1.1 International rules ... 25
9.1.2 Mandatory carriage of fuel for an extra alternate ... 26

10 DISCUSSION ... 29

10.1 Relevance of operational requirements to risk ... 29
10.2 Risk mitigants ... 29

11 CONCLUSION ... 33

12 GLOSSARY ... 35

13 APPENDIXES 37
13.1 Appendix A: Test algorithms 37
13.1.1 Part 1..37
13.1.2 Part 2..39
13.1.3 Part 3..39
13.1.4 Part 4..41
13.1.5 Part 5..41
13.2 Appendix B: Domestic and international rules for weather alternate requirements 42
13.2.1 ICAO requirements 43
13.2.2 Australian requirements...44
13.2.3 US requirements 46
13.2.4 New Zealand requirements..47
13.2.5 UK requirements 48
13.3 Appendix C: Landing and alternate minima.....................................50
13.4 Appendix D: Operational equipment and limitations for the ‘average’ aircraft that were used for this analysis 58
13.5 Appendix E: Basic data used for analysis 59

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
B2004/0246	June 2006	76	1 921092 50 5

Publication title

Destination Weather Assurance: Risks associated with the Australian operational rules for weather alternate minima

Author(s)

Langford A., Watson M.

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Acknowledgements

The Australian Bureau of Meteorology

Abstract

Civil aviation safety is based on managing the safety of knowledge of things that can affect the safety of flight. One of these sets of knowledge is confidence that the facilities at the destination will be good enough to give confidence of a safe landing. Weather at the destination can affect the safety of a landing. Detailed historical records are kept of weather observations and weather forecasts. This study has analysed the level of statistical confidence that has been achieved with destination weather forecasts under various conditions. It has also looked at other mechanisms that are or could be used to reduce the risk in addition to the existing methods.

EXECUTIVE SUMMARY

Airline transport operations aim to maintain a high level of safety by ensuring that every safety-critical aspect of a flight is managed in a way that ensures the effective control of associated safety-critical risks.

The reliability expected when managing any safety-critical aspect of an air transport flight is indicated in the International Civil Aviation Organization Continuing Airworthiness Manual 1995. This document primarily relates to engineering issues, but also comments on the expected reliability for safety-critical operational issues. The manual refers to '… potential failure conditions which would prevent continued safe flight and landing'. The required level of reliability for any single operational safety-critical system can be inferred from this document as 1×10^{-8} for each flight. This figure is used to provide a comparison.

One safety-critical aspect of air transport operations is confident knowledge that before an aircraft takes off, it can land safely. A number of issues are relevant in making this assessment, including confidence that the weather at the destination will enable a safe landing. This study has examined weather data to seek to measure the level of confidence that can be obtained in predicting a destination's weather by the use of weather forecasts. The reliability of weather forecasting as a safety-critical aspect of air transport operations was selected in part because of the availability of extensive meteorological records for major Australian airports.

An examination was conducted of the Australian Transport Safety Bureau occurrence database, which found 62 occurrences in the nine years leading up to the end of 2004, in which unforecast destination weather degradation had been a contributing factor to the occurrence. The occurrences were sorted by reference to defences that were appropriate to the occurrence.

Operational rules are used as tools for assessing if the weather conditions at a flight's destination will be better than specified meteorological minima, enabling a safe landing. This study has made a practical assessment of the effectiveness of these rules by analysing large numbers of historical weather reports and forecasts for a number of major Australian airports. The number of events was counted when the weather at these airports had deteriorated sufficiently that a safe landing could not be assured. Each of these events was then compared with corresponding forecasts to determine whether the forecast had provided adequate warning of the impending deteriorating weather, according to Australian operational rules. This could provide knowledge to allow more fuel to be carried, enabling an aircraft to divert to an alternate airport if the destination weather was below alternate minima.

There are many different types of air transport operations in Australia. Following discussions with air transport operators, two aircraft types were selected as a representative sample of high capacity and low capacity air transport operations. Different flight durations were also selected to reflect average flight times.

The Bureau of Meteorology provided the large data sets that were required for conducting this analysis.

The results indicated that the frequency of events when the weather was below the destination landing minima varied from 0.4 per cent to nearly 2.0 per cent, depending on the airport. In contrast, the forecast failed to advise pilots of the below landing minima condition between 10 per cent and 60 per cent of the time, again depending on the airport. The combination of these figures led to frequencies of these potentially unsafe events between 0.05 per cent and nearly 1 per cent.

This frequency does not relate to the actual frequency of weather related occurrences, sand other processes were examined for their effectiveness as mitigators against this risk

Results obtained from the use of Australian operational rules were compared with operational rules that were developed as an average of the requirements in some other countries with large air transport operations. The European standard practice of always carrying sufficient fuel to fly from the destination to an alternate, irrespective of the destination's weather, was also assessed for its potential impact on risk involving Australian air transport operations. While this method had a significant effect on the risks associated with unforecast deteriorated weather, the European operating environment is very different, with on the one hand generally less benign weather, but on the other hand more alternate airports available than in Australia.

The use of en-route weather reports for updating operational decisions as a potential risk mitigant was examined to assess their capacity to provide a timely en-route warning that the destination weather would prevent a safe landing from being assured, thereby enabling an early diversion to an alternate airport.

Results obtained from using terminal aerodrome forecasts were compared with results obtained from using trend type forecasts for providing an effective warning of deteriorated weather at a flight's destination.

A comparison for these results was achieved from a survey of the Australian Transport Safety Bureau occurrence database, which found 62 occurrences in the nine years leading up to the end of 2004 where unforecast destination weather degradation had been a contributing factor to the occurrence. The occurrences were sorted by reference to defences that were appropriate to the occurrence.

The comparisons in this study suggests that the use of Australian rule sets alone to assess the risk of deteriorated weather at a destination airport by themselves does not ensure a level of safety as described in the International Civil Aviation Organization Continuing Airworthiness Manual. The fact that there have been very few serious incidents or accidents associated with landing at a destination with unforecast deteriorated weather, suggests that one or more other factors are also reducing risk. From this it may be suggested that although other risk mitigants appear to be effective, they may not be known or consistently managed.

200404385 Boeing 747-438

The aircraft landed with insufficient fuel due to unforecast fog at the destination. Prior to departure, weather forecasts had indicated that the carriage of extra fuel was not required.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft diverted to an alternate destination and landed in weather above the landing minima, but below the minimum fuel requirement.

ABBREVIATIONS

AIP	Aeronautical Information Publication
ATSB	Australian Transport Safety Bureau
BoM	Bureau of Meteorology
CFIT	Controlled flight into terrain
ETA	Estimated time of arrival
IAL	Instrument approach and landing
ICAO	International Civil Aviation Organization
IMC	Instrument meteorological conditions
NZ	New Zealand
TAF	Terminal aerodrome forecast
TTF	Trend type forecast
UK	United Kingdom
US	United States
VFR	Visual flight rules

1 INTRODUCTION

The aim of the Australian Transport Safety Bureau (ATSB) is to help maintain and improve transport safety. The ATSB investigates aircraft occurrences (accidents and incidents) in order to identify the factors that contributed to an occurrence and to seek to prevent a recurrence. The ATSB also conducts research into matters that affect or may affect safety.

Aviation safety can be enhanced by aiming to seek for a known and provable zero frequency of all factors of a flight that may compromise its safety. Such safety-critical aspects are sometimes independent (such as the reliability of power sources, wing structural integrity and navigational fidelity), and therefore the level of safety of the whole flight may be no more reliable than the least reliable safety-critical aspect of the flight. The safety of a flight may be only as strong as its weakest link.

Historically, transport aircraft operations have been demonstrably successful in identifying and controlling safety-critical risks. However, effective analysis can often be difficult because analysis of the probability of a specific risk is very low, therefore secondary indicators, such as the use of processes for protecting against risk, may be used to imply a relationship with risk.

Aircraft fly in a variable operating environment, largely affected by weather conditions that have the potential to affect the safety of flight. The availability of extensive records of weather forecasts and reports makes it easier to analyse some safety-critical factors directly, rather than needing to rely on analysis of the effects of secondary indicators.

Adverse weather has the potential to affect safety. Weather associated occurrences generally fall into several groups:

- Visual flight rules (VFR) flight into instrument meteorological conditions (IMC): occurrences when a pilot is not authorised to fly without reference to an external visible reference to the horizon, but does so. The pilot’s loss of understanding of the aircraft’s orientation leads to a loss of control of the aircraft.
- Controlled Flight Into Terrain (CFIT): These occurrences normally only happen when an aircraft is flying in an environment where it is not possible to see outside the aircraft, because the aircraft is flying in cloud or because it is dark. An accident may occur if the pilot is unaware of the vicinity of terrain, and the aircraft collides with that terrain.
- Destination weather deterioration:
    - Lack of timely weather information reporting. Occurrences when the destination weather has deteriorated shortly before landing; however a weather information update was not transmitted to the pilot in time to help make an informed decision about the landing.
    - Inaccurate destination weather forecasting. Occurrences when the weather at the destination deteriorated beyond that which was both forecast and required to assure a safe landing, but the flight had been planned on the assumption that a safe landing at the destination could be assured, based on pre-flight weather forecasts.

Accidents associated with VFR into IMC normally involve a pilot making a decision based on a visual interpretation of the weather during flight. Although the pilot should have knowledge of the weather before flight, the actual decision on whether to continue is made during the flight when a pilot is confronted with the weather.

Accidents associated with CFIT normally involve a lack of awareness of the proximity of terrain, associated with a lack of forward visibility. This accident type normally involves a misunderstanding of the relationship between the aircraft and the terrain. Any lack of forward visibility is considered to be a precondition of the event, and is not normally considered as a factor.

In contrast, occurrences associated with unforecast destination weather involve decisions that are made before flight, based on information that was available before flight. This occurrence type is associated with flight planning decisions, with a greater potential for information from a forecast to affect a risky situation, compared the other occurrence types described above.

The Bureau of Meteorology (BoM) routinely archives many forecasts and associated weather reports, which provides a greater opportunity to compare all potential flights with associated weather forecasts, enabling analysis of related operational risk types. VFR into IMC- or CFIT-type occurrences are harder to analyse, as an assessment would rely on both consistent occurrence reporting and accurate knowledge of flight populations in order to provide adequate data sets to permit meaningful analysis.

The probability of an increase in operational risk associated with unforecast weather deterioration at the planning stage of a flight has been considered to be proportional to the probability of unforecast weather deterioration. This correlation and the availability of extensive weather records has enabled an analysis of the risks to flight associated with unforecast weather deterioration.

This study has therefore examined the probability of various types of unforecast weather deterioration, and compared reported occurrence types that could be expected from the results.

The BoM has participated in this project by providing large datasets of historical meteorological information, which have been used as the primary data source. The ATSB is grateful to the BoM for its assistance.

200104756 Boeing 747-438

During the approach to Sydney, the crew reported that the weather was observed to be significantly worse than that indicated in the 3-hour trend forecast held by the crew. After several attempted approaches on different runways the crew were required to perform an auto landing on runway 34L due to the aircraft's fuel situation.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently conducted a category three autoland in weather below the destination landing minima.

2 ENGINEERED RELIABILITY

The safety of airline operations relies on the successful management of many safety-critical aspects of every flight. These include confidence in the structural integrity of the aircraft, the ability of the flight crew to manage the flight, and the quality of the information available for managing the flight.

The International Civil Aviation Organization (ICAO) Continuing Airworthiness Manual 1995 (Doc 9642-AN/941) addresses the certification requirements for aircraft operation. It states (1.2.4):

> In assessing the acceptability of a design, it was recognized that rational probability values would have to be established and these were set on the following basis:
>
> a) historical evidence indicates that the risk of a serious accident due to operational and airframe-related causes is approximately one per million hours of flight. Of this figure, 10 per cent can be attributed to failure conditions caused by aircraft system problems. On this basis, it was considered that serious accidents caused by systems should not be allowed a higher probability than this in new designs. It is therefore required that the probability of a serious accident from all such failure conditions should not be greater than one in ten million flight hours, i.e. a probability of less than 1×10^{-7}; and
>
> b) to be satisfied that this target can be achieved, it is necessary to collectively analyse numerically, all the systems on the aircraft. For this reason, it is assumed, arbitrarily, that there are about 100 potential failure conditions that would prevent continued safe flight and landing. The target risk of 1×10^{-7} was apportioned equally amongst these conditions, resulting in a risk allocation of not greater than 1×10^{-9} to each one. Thus, the upper risk for an individual failure condition that would prevent safe flight and landing is set at 1×10^{-9} for each flight.

This statement has been used to provide a measure for the reliability of engineered structures in an aircraft. The statement implies that 90 per cent of failure conditions in these circumstances may be operational, however the probability values provide an indication of a similar order of magnitude. These figures have therefore also been considered as a reasonable measure for an acceptable expectation of the probability of operational safety-critical failure conditions in airline operations.

A number of procedures are used to reduce the risk of specific safety-critical failure conditions. These include the use of engineered redundancy systems, staggered maintenance and the use of sophisticated maintenance management systems. Engineered systems, such as the assessment of the probability of a structural failure, can be assessed using standard engineering techniques. However, the influences of human interactions, found more in operational safety-critical systems, are harder to quantify or assess. In complex, high-risk technological systems that require human input, various approaches have been adopted to enhance safety and reliability. These include the extensive use of procedures and guidelines, development of organisational safety cultures, education and training, and redundancy systems such as multi-crew operations and multiple information sources. These approaches to increasing reliability in human-based safety-critical processes are focussed on enhancing identification of out-of-tolerance events and the development of mitigating strategies to reduce the probability of such events leading to a negative outcome.

A number of factors can compromise the safety of a landing at a destination. The factors must be considered at the flight planning stage to assure a safe landing at the destination. The main factors are:

- the destination runway must be big enough and strong enough to assure that a safe landing can be conducted
- the provision of specified lighting at the destination aerodrome if the estimated arrival time is at night
- the provision of specified navigational equipment to assist with finding the aerodrome and descending to a height where a visual approach and landing may be conducted
- weather conditions are better than specified destination alternate weather minima[1].

All these safety-critical criteria have to be met for the airport conditions to be considered adequate to assure a safe landing. The reliability of the assumption of landing safety will be adversely affected by any change in the ability to assess any one of these criteria.

The reliability of runway size and strength, airport lighting equipment and navigational instruments can be assessed by using conventional engineering and statistical techniques. However, weather forecasts have not been assessed for reliability when using the criteria defined within Australian operational flying rules for determining if the destination weather will enable a safe landing.

A ‘failure condition’ as referred to in paragraph b) above has been considered, for the purposes of this study, as a circumstance when the destination weather is sufficiently poor to preclude an assured safe landing in accordance with published criteria, and the aircraft does not have sufficient fuel to continue to an alternate airport where the weather is above the landing minima. Such an event would prevent ‘continued safe flight and landing’, thereby fulfilling the requirements for a ‘failure condition’. An aircraft is less likely to have sufficient fuel to continue from a destination to an alternate airport at the flight planning stage, if the destination’s weather forecast indicated that the weather would be good enough to assure a safe landing, as the forecast provided no indication for a need for extra fuel. An event when a destination’s weather was not good enough to enable a safe landing, combined with no warning of this weather in the corresponding forecast was therefore considered as an ‘unsafe event’ for the purposes of this study.

The rules for considering weather-related alternate requirements were different in all the various countries’ requirements that were examined[2] as a part of this study.

---

[1] Weather forecast conditions (known as alternate weather minima) that are used at the flight planning stage for assessing if an aircraft will be able to land at the destination are more conservative than the actual minimum weather conditions that are necessary to enable a safe landing. The different requirements are intended to allow for unforecast weather deteriorations.

[2] Rules for weather alternates in some other countries are in Appendix B.

3 METHOD

This study examines records of weather data to analyse the reliability of weather forecasts as a tool for assuring a safe landing. This has been done by comparing landing minima information derived from weather reports with corresponding alternate minima information derived from weather forecasts.

3.1 Aircraft types

Following discussion with air transport operators, two generic aircraft types were considered to represent significant groups of commercial instrument flight rules (IFR) air transport in Australia, and operating criteria were selected that were an average of what is used in practice by operators of these aircraft types.

A Boeing 737 was first considered. Australian Boeing 737 operators have different operating limitations that are accepted by the Civil Aviation Safety Authority, so for this assessment a compromise set of operational limitations was selected to provide an average representative sample. It would not be difficult to amend and run these data analyses with any specific airline's operating limitations.

A Piper Chieftain PA31-350 aircraft type was also considered as a typical example of a piston multi-engine aircraft below 5,700 kg. Although aircraft of this type have a lower performance category[3] (indicating that the aircraft's speed just before touching down to land is lower), which may enable a safe landing in worse weather conditions than an aircraft with a higher performance category. This aircraft type generally has less sophisticated navigation equipment to facilitate an 'unsafe' approach in an emergency, and also has less fuel range available for diverting to an alternate aerodrome (because of less fuel capacity). It also generally has a lower crosswind limit for landing compared with a Boeing 737. These factors reduce the capability of the aircraft type to land in poor weather conditions. For the purposes of this study, this aircraft type was considered not to meet the equipment requirements for special alternate minima[4], providing a contrast with the Boeing 737 aircraft type to enhance the potential for analysis.

The defined operational specifications used for these aircraft types in this study are in Appendix D.

3.2 Types of limiting weather phenomena

A number of different types of weather phenomena are considered capable of compromising a safe landing. The phenomena types that are considered when assessing Australian weather forecasts are:

- Visibility. The minimum horizontal visibility for the pilot's visual reference before landing.
- Cloud base. The lowest height above the ground at which there is not more than half the sky covered by cloud.
- Crosswind or downwind component. The maximum crosswind or downwind component for the intended landing runway.

---

3 'Performance category' is defined in Aeronautical Information Publication (AIP) ENR 1.5.1.2.1, dated 25 November 2004. It relates to an aircraft's speed as it crosses the runway threshold when landing.

4 Special alternate weather minima are lower, that are available for some specified instrument approaches if the aircraft has specified dual navigation instruments. For more detail, see AIP ENR 1.5.6.2.1 , dated 25 November 2004.

- Thunderstorms. Their existence or their associated severe turbulence.

Each of these phenomena types has its own implications when considering information from weather forecasts or reports about their existence.

3.2.1 Visibility

Many modern airliners are equipped to enable a safe landing to be conducted when the horizontal visibility is reduced sufficiently to prevent a pilot from gaining an external visual reference prior to landing. In such a situation however, extra navigation equipment is also required on the ground to ensure a safe landing; however no Australian runways are adequately equipped to enable such an approach. A minimum horizontal visibility is therefore always required for a landing in Australia to ensure that the pilot has adequate and timely visual reference with the runway before landing. A landing approach is conducted at a higher airspeed in an aircraft with a higher performance category, so a greater visibility may be required, particularly for conducting a circling approach to land in which a greater turn radius is also required associated with the higher airspeed.

3.2.2 Cloud base

Clouds can form at a low height above the ground, irrespective of the visibility underneath a cloud base, leading to the need for an instrument approach. If a pilot has to acquire a visual external reference in sufficient time to conduct a visual approach to land, there needs to be sufficient time between descending below the cloud base and touch down, providing the pilot with the opportunity to manoeuvre adequately, either to line up for a runway approach or to permit a circling manoeuvre to line up for a different runway during the visual segment of a circling approach. Aircraft with a higher performance category may have higher cloud base minima, particularly for circling instrument approach minima and alternate minima to allow for a higher airspeed and turning radius.

3.2.3 Crosswind and downwind

All airliners have defined maximum safe crosswind and downwind limits for landing. An alternate is required if a weather forecast does not provide confidence that a landing may be conducted on an available runway at the destination without exceeding crosswind or downwind limits. However, a pilot may still attempt a landing at a destination, as the wind may have reduced.

3.2.4 Thunderstorms

Thunderstorms are normally transient weather phenomena in which it is not safe to land because of the associated extreme weather, which rarely lasts for more than an hour. Aviation weather forecasts usually indicate this by indicating that any weather deterioration because of thunderstorm activity will last no more than 30 or 60 minutes. A pilot flying to such a destination can carry extra holding fuel for 30 or 60 minutes on the basis that a thunderstorm-based weather deterioration will improve within the forecast duration. Alternatively, the pilot may elect to carry fuel to fly to an alternate aerodrome that does not itself have a requirement for an alternate. Occasionally thunderstorms are continuously forecast. In these extreme circumstances, the only option is to carry fuel to fly to an alternate aerodrome that does not itself have a requirement for an alternate; carrying holding fuel is not an acceptable option.

3.3 Destination weather alternate assessment

A pilot has a number of opportunities during a flight to detect if the destination aerodrome's weather will be below the landing minima and to plan for an alternate course of action. Pilots are required to assess the destination weather forecast when planning before flight. If the destination forecast is below the alternate weather minima criteria, they are required to carry sufficient fuel to divert to an alternate aerodrome, which itself has no requirement for an alternate. The alternate minima would require less capability than the landing minima to allow for a limited deterioration in a destination's weather without exceeding the landing minima and thereby still to permit a safe landing.

If a flight is initiated on the basis of forecast weather information indicating that it will be safe to land at the destination, but on arrival it turns out to be unsafe, then this is considered to be an 'unsafe event', because the opportunity to plan for a safe alternate destination before the flight had been deemed unnecessary at the planning stage. The criteria for outcome safety are defined in Table 1.

Table 1: Matrix of 'safe event' conditions for weather forecasting criteria

	Destination forecast above alternate minima	Destination forecast below alternate minima
Destination actual weather above landing minima	Safe event	Safe event
Destination actual weather below landing minima	Unsafe event	Safe event

3.4 Data sources

The BoM provided large datasets of Terminal Aerodrome Forecasts (TAF) and weather reports for major aerodromes. The forecast sites used were: Alice Springs, Brisbane, Cairns, Rockhampton, Townsville, Launceston, Melbourne, Adelaide, Darwin, Perth, Canberra, Coffs Harbour and Sydney. Approximately 100,000 reports were provided for each airport. Trend Type Forecasts (TTF) were also provided for Brisbane, Cairns, Rockhampton, Townsville, Melbourne, Adelaide, Darwin, Perth, Canberra and Sydney; however, the data sets were smaller as they were not centrally archived nor retained for as long as TAFs.

Weather reports that did not have corresponding weather forecasts (with an appropriate time offset) were also discarded, so that no weather reports were considered unless they could be compared with their corresponding weather forecasts. This process removed excess weather report information that could skew the results.

The remaining airport weather reports were then filtered for textual errors or missing observations. The only exception was for reports in which with visibility observation had been replaced with a blank field. Many weather reports use observations from an automatic weather station instead of observations from an approved observer. Some automatic weather stations do not include a sensor for measuring horizontal visibility, and that data is omitted from the report. The data provided for some airports have weather reports with a significant proportion without a visibility observation. Filtering these weather reports from the datasets would have led to a large reduction in available data for some airports.

In the cases where visibility data is missing from a weather report, no comparison on visibility can be made with weather reports and their corresponding forecasts. It is possible however to make a valid comparison with weather reports and their corresponding forecasts based on the remaining weather reports that do have a visibility, although the sample size will be smaller. Furthermore, it is still possible to make a valid comparison on the other weather phenomena even when the visibility data from weather report is missing.

Different numbers of weather reports and forecasts were available for each airport and for each forecast type. The actual numbers of unsafe events could not therefore be compared among airports; however, the ratios for all weather events, all below landing minima weather events and 'unsafe' weather events could be compared for each airport.

The criteria for landing and alternate weather minima were assessed using instrument approach and landing (IAL) charts for the respective airports that were valid in December 2004. Instrument approaches for each airport were sorted so that the most capable instrument approach was given first preference. The criteria that were used in this study are in Appendix C. There have been small changes in minima at various airports over time; however, these changes were not considered to have a significant effect on the results, as the differences between respective landing and alternate minima would remain similar.

The method used in this study was firstly to count and examine the large datasets of weather reports. Then all weather reports from which an aircraft could be expected to land safely according to the defined minimum weather landing criteria were discarded. Against the remaining weather reports, forecasts that were issued and relevant at set time periods before that report were then examined to assess whether they provided sufficient warning (by forecasting weather below the alternate minima), thereby informing the pilot of the need to plan for a safe alternate. The frequency of events when *both* an 'unsafe for landing' weather report, *and* its corresponding forecast indicated that it would be 'safe for landing' were counted. These events were called 'unsafe events'. The test algorithms are described in greater detail in Appendix A, part 1.

3.5 Data variables

3.5.1 Time between forecast issue and landing

The research plan was designed to examine a representative sample of air transport flights conducted in Australia. Following discussion with operators and an assessment of average route lengths, flights of 1 and 3 hours were considered, with an assumption that the destination weather forecast was obtained 1 hour before the commencement of the flight. A 'time offset' was therefore used for selecting an appropriate weather forecast to compare with respective landing weather conditions, where the 'offset' was the time period between the planned time of landing and the time when a forecast would have been sought when planning for that flight. Two results were obtained for each aircraft type at each airport, with either a 2-hour forecast time offset or a 4-hour forecast time offset.

3.5.2 TAF and TTF

Trend type forecasts were also issued for the majority of the examined airports. A TTF is valid for 3 hours, and must be used in preference to a TAF for assessing destination alternate requirements during its period of validity. This means that for the 1-hour flights, the TTF would have been used in preference to the TAF if a TTF was available, because the flight would land within the period of forecast validity for the TTF. This study has also provided the opportunity to compare the forecasting accuracy of TTFs with TAFs, and hence the safety afforded by using the different forecast types when planning fuel requirements for a flight. The results are discussed in Section 6.

The methods of storage and retrieval of TTF records in the BoM are different from the methods for TAFs, so the nature of the samples was different. The population of TTFs was smaller than the population of TAFs. Furthermore, the frequency of issue of TTFs may vary more than for TAFs, depending on the weather; as the frequency of issue of TTFs may be more variable during deteriorated weather. The methods for ensuring that the populations were comparable are described in Appendix A, part 5.

The tabulated results are in Appendix E.

3.6 Comparisons

Three main data populations were therefore available for analysis from each airport, for each aircraft type, with each population being a subset of the previous population.

1. The total population of events that were considered (as defined in section 3.4).
2. The total population of events when the weather was below the landing minima.
3. The total population of 'unsafe events'.

Comparing 2 with 1 indicates the frequency of deteriorated weather events at a particular airport. Comparing 3 with 2 indicates the frequency of deteriorated weather events that are also 'unsafe events' at a particular airport. Comparing 3 with 1 indicates the frequency of 'unsafe events' at a particular airport.

200104266 Boeing 767-238

During the descent, the crew was advised that the weather conditions at Melbourne had deteriorated below those reported in the current weather forecast. The crew reported that no fuel allowances had been made for weather based on the forecast.

ATSB Summary

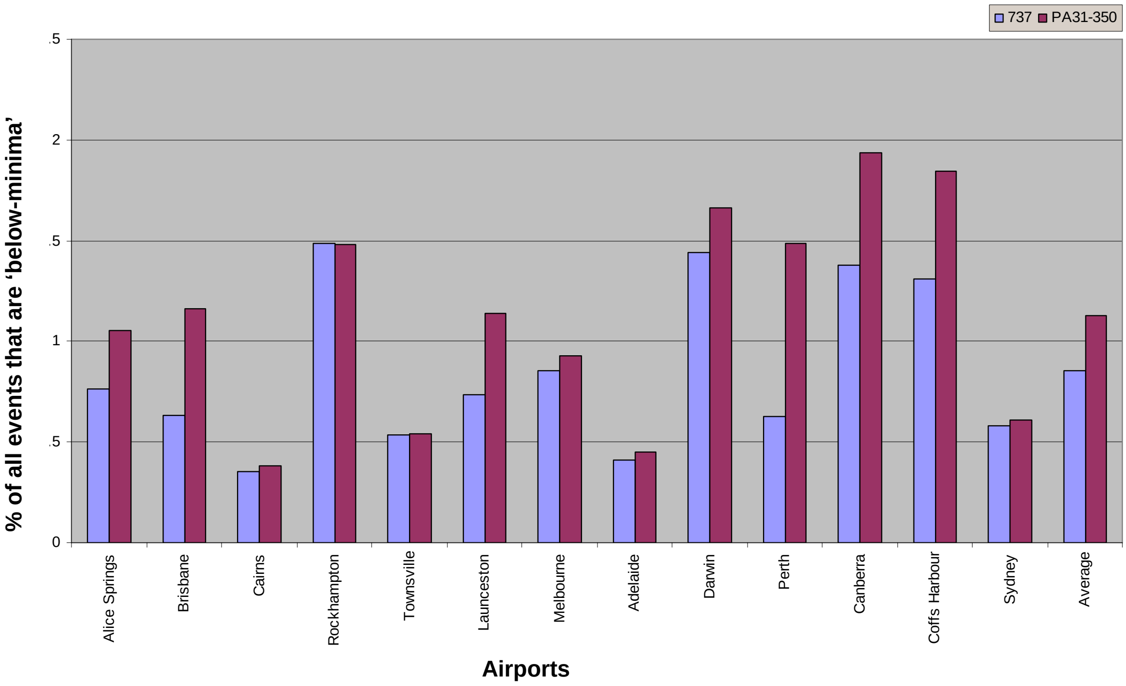
Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather above the destination landing minima.

4 BELOW LANDING MINIMA EVENTS

4.1 Frequency of ‘below landing minima’ events

The first selection process sorted and counted the events when the weather was below landing minima at each airport for each aircraft type. The fraction of weather observations at each airport that presented below landing minima conditions was compared with the number of all weather observations for each aircraft type is presented in Figure 1. The data are presented in Table 7.

Figure 1: Frequency of below landing minima events as a percentage of all weather observations at specific airports



The percentage frequency of below landing minima events compared with all weather events varied from 0.36 per cent for 737 aircraft at Cairns to nearly 2 per cent for a PA31-350 at Canberra and Coffs Harbour.

In most cases, there were more below landing minima events for the PA31-350. In general, the factor that limited the capability to land more for this aircraft type was its lower crosswind limit when runway approaches were used. Circling approaches permitted a landing on a different runway once visual reference had been achieved, which allowed more than one runway option when considering a strong crosswind (Rockhampton was the only airport in this study in which circling approaches were considered). However, the circling approach cloud base and visibility landing minima were generally require less capability than an equivalent runway approach. The lower capability requirements associated with the visibility limitations at Rockhampton for performance category C, 737 aircraft increased the number of below-minima events for performance category C aircraft compared with performance category B, PA31-350 aircraft.

4.2 Types of limiting phenomena that make an event 'below landing minima'

All the specific limiting phenomena types that could create a below landing minima event were counted from the below-minima weather reports for each airport and aircraft type, to identify the prevalent limiting factors for each airport. The frequency of below landing minima visibility events has been normalised using the frequency with which visibility data was missing from weather reports. These data are presented in Table 10. The proportions of different limiting phenomena types in the below landing minima events for each aircraft type at each airport are presented in Figure 2. The data are presented in Table 9.

Figure 2: Ratios of limiting phenomena types in below landing minima events by aircraft type at each airport

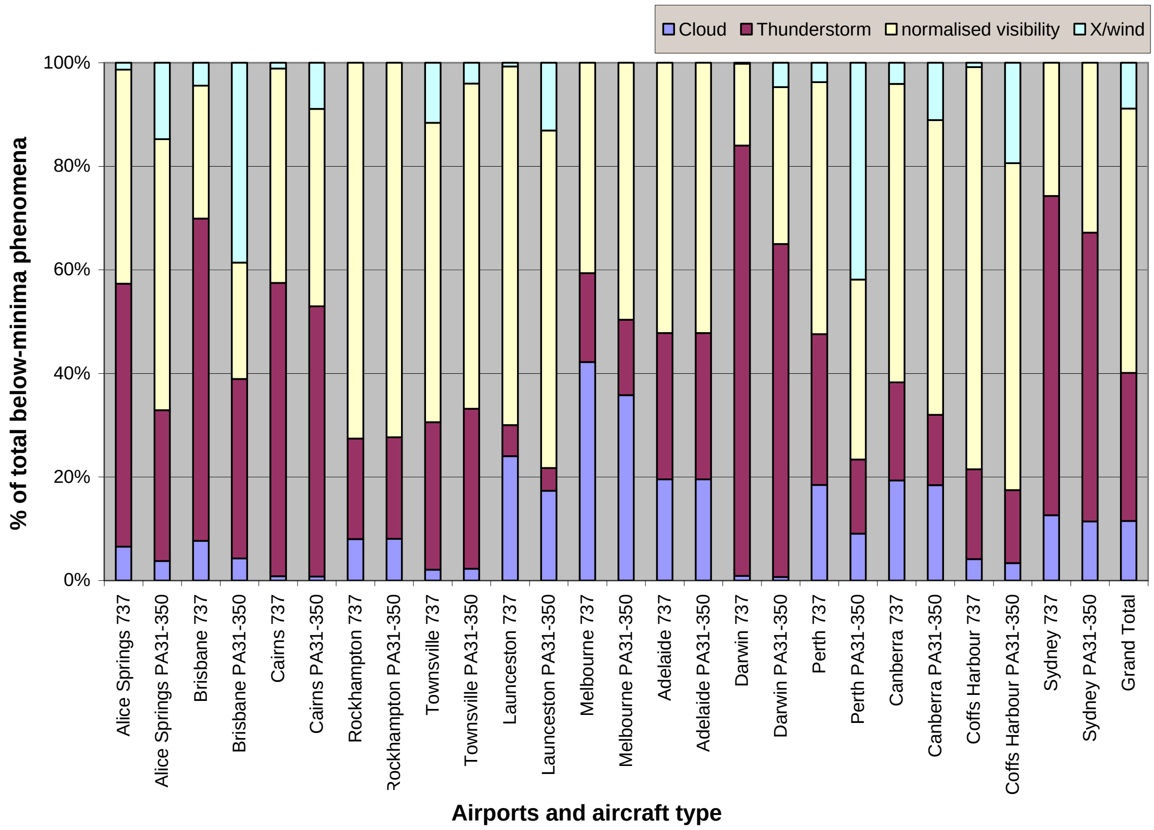


Figure 2 presents the ratios of the different types of limiting phenomena compared with the total number of phenomena for each aircraft type at each airport. The graph may therefore be used in conjunction with Figure 1 to give an indication of the overall frequency for a specific limiting phenomenon at a particular airport. Some below landing minima events had more than one below landing minima phenomenon.

A forecast indicating thunderstorms does not always preclude a safe landing, as the generally transient nature of thunderstorms means that there is a probability that there will be no thunderstorm on arrival at the destination despite the forecast. In contrast, a forecast of low visibility, low cloud base, or high crosswind that exceeds the landing minima may be more likely to preclude a safe landing, because the phenomenon type is not usually transient (unless it is described as such on the forecast), unlike thunderstorms. For example, the results for Alice Springs show a relatively high proportion of thunderstorms; however, the total number of below-minima events is relatively low, reflecting the normally benign weather at that airport. Melbourne has a relatively high proportion of low cloud base phenomena, and Canberra's relatively high proportion of low visibility phenomena reflect its reputation for being foggy on winter mornings. In all cases where crosswind limits are a factor, the higher crosswind limits of the 737 make a significant difference to its capacity to land safely.

All the below landing minima events were also sorted according to the phenomena type or groupings of types that made them below landing minima, but no significant findings could be determined from the numbers of the different groupings of phenomena types. The results are presented in Appendix E, Table 11.

4.3 Similar information

The Bureau of Meteorology monitors the quality of its forecasting product by measuring the frequency of accurate forecasts. However, this system compares 'like with like' and cannot be used to compare destination alternate minima from a forecast against different landing minima requirements from a report. This system was therefore not considered appropriate for this study.

200104228 SA227-DC Metroliner

When about 60 NM inbound to Adelaide, at about 1830 CST, the pilot of the Metroliner was advised by ATS of hazardous weather conditions at the destination airport. The pilot requested current weather conditions for the planned alternate aiports and was advised of the weather by ATS. The actual conditions indicated that those planned alternate airports now had alternate requirements, hence were not suitable for a diversion. The pilot declared a PAN* phase due to insufficient fuel for a suitable alternate.

The pilot was cleared by ATS to conduct an ILS approach, and landed the aircraft safely on runway 23.

* PAN is an urgency phase that is normally broadcast by radio.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather above the destination landing minima.

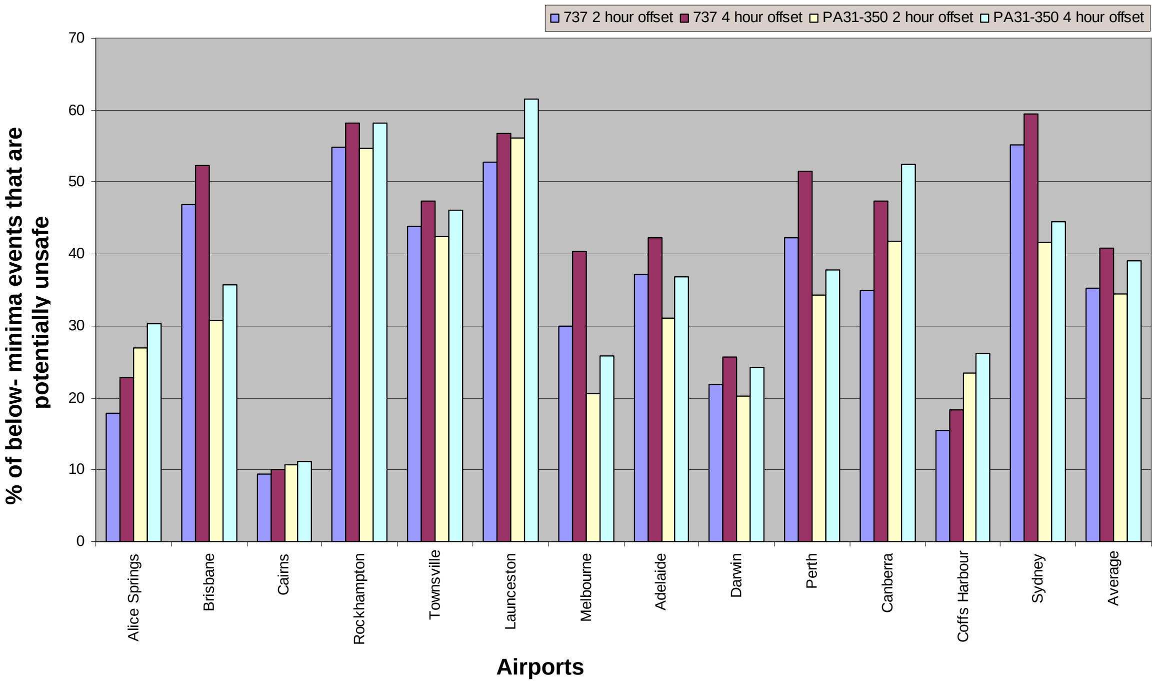
5 POTENTIALLY UNSAFE EVENTS

The concept of describing an event as 'potentially unsafe' is only used in this study to describe a specific combination of circumstances that describe the event. The actual relevance of a 'potentially unsafe event' in itself, and the risk that it can pose to the safety of aircraft operations is considered in section 10.1.

5.1 Forecast prediction accuracy for below landing minima events

The population of below landing minima weather events described in Figure 1 was compared with TAF weather forecasts with a 2-hour time offset and a 4-hour time offset to assess the accuracy of the forecast prediction of the below landing minima event for each aircraft type, using Australian alternate weather rules as the prediction tool. The frequencies of below landing minima events that were incorrectly predicted through the application of alternate minima criteria to the relevant forecast, (and were therefore classified as 'potentially unsafe events',) are depicted in Figure 3. The data are presented in Table 7.

Figure 3: Fraction of below landing minima events that were not predicted by forecasts at a 2-hour time offset and a 4-hour time offset for airports and aircraft types



The forecasts did not provide an accurate prediction for approximately a third of below landing minima events. Three airports did not have special alternate minima: Cairns, Rockhampton and Sydney. There was little difference between the results for the PA31-350 and the 737 at these airports, but some airports with special alternate minima showed a higher probability of a potentially unsafe event if special alternate minima were used for assessing alternate requirements. This was evident from a comparison of the results at Brisbane, Melbourne and Perth. With other airports, where the 737 was considered to be using special alternate minima, but the PA31-350 was not, the 737 had a higher frequency of potentially unsafe events. The relevance of the extra risk mitigants associated with the equipment requirements for special alternate minima are considered in section 10.2.

200103086 SA 227-DC Metroliner

The aircraft departed Melbourne with 2,200 pounds of fuel, which was more than required for the indicated weather conditions. On arrival, weather conditions were worse than forecast and two IFR approaches to the minima were unsuccessful. The crew then elected to divert to Swan Hill where two IFR approaches were also unsuccessful. The aircraft was cleared back to the original destination and arrived with 400 pounds of fuel remaining. The crew of another aircraft, which was ahead, agreed to hold thus allowing them to carry out an IFR approach first. This time they became visual at 900 ft and landed without further incident.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft diverted to an alternate destination and landed in weather above the landing minima, but needed extra fuel that was not required to be carried at the start of the flight.

200101587 PA-31-350

During the approach to Bankstown the pilot performed a missed approach due to fog. An ILS approach was attempted at Sydney with the same result. The pilot advised ATC that the aircraft's fuel level was critical with 40 minutes remaining and no reserves. The aircraft was not equipped with a DME, so the lowest available altitude on approach at Bankstown was 980 ft. The pilot was therefore provided with radar vectors and constant radar distances on the runway 11C NDB DME approach to Bankstown, this allows a lower approach minimum of 680 ft. The pilot became visual at 700 ft and joined the circuit with ATC estimating the fuel remaining to be 25 minutes.

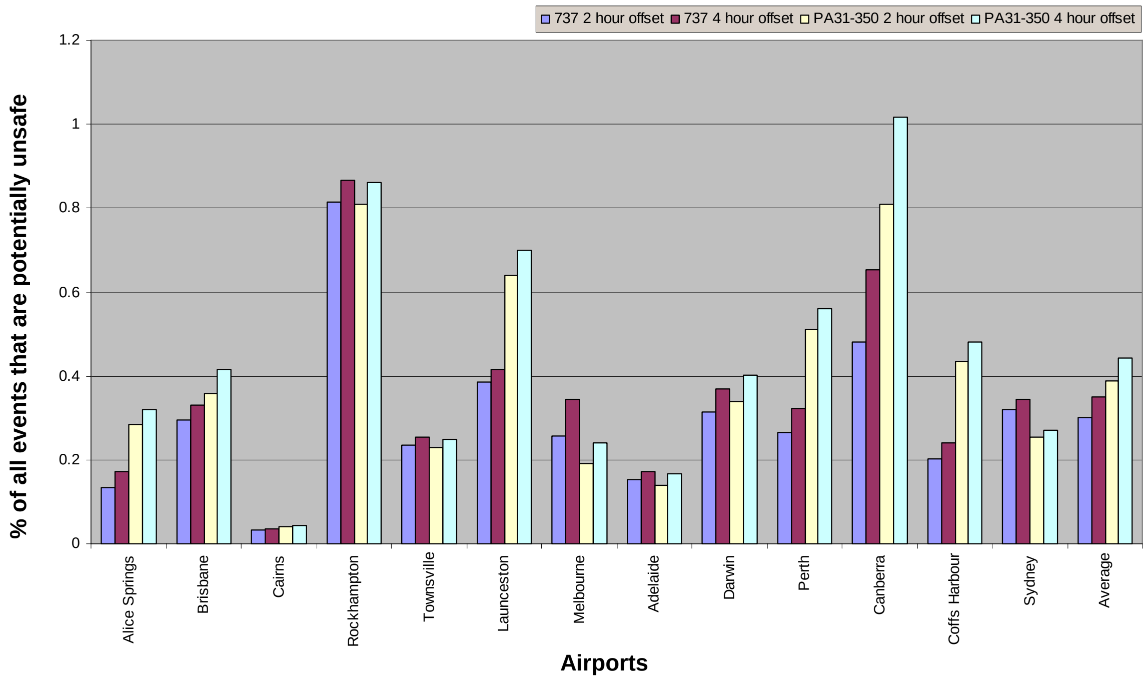
ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft landed in weather at the destination landing minima, but with below minimum fuel reserves.

5.2 Forecast prediction accuracy for below landing minima events, compared with all weather events

The population of all recorded weather events for which a corresponding TAF existed was compared with the events corresponding TAF weather forecasts with a 2 hour offset and a 4 hour offset to assess the accuracy of the forecast prediction of below landing minima events for each aircraft type at each airport, using Australian alternate minima and landing minima weather requirements as the prediction tool. The frequency of unsafe events compared with all events is depicted in Figure 4. The data are presented in Table 7.

Figure 4: Fraction of all weather events that were not correctly predicted as below landing minima by TAF forecast at a two-hour offset and a four-hour offset for airports and aircraft types



The mean for the aggregated potentially unsafe events was 0.35 per cent. This meant that the average major Australian airport weather forecast would have given a 'unsafe' condition approximately one time in 300. There were significant differences among airports, varying from 0.04 per cent in Cairns to 1.2 per cent in Rockhampton.

Up to 48 weather reports were considered for each airport every day for this study, so there could be a potentially unsafe event (as defined for this study) at a major airport on average every 6 days.

There were 1,207,218 traffic movements at these airports in 2004[5]. There were no significant weather-related landing accidents during this period at these airports, so it would appear that some other forms of risk mitigant had been effectively reducing the risks associated with unforecast destination deteriorated weather. These risk mitigants are discussed later in the report in section 10.2.

5 http://www.airservicesaustralia.com/reports/movements/calytd2004.pdf accessed on 19 March 2005.

200201483 Boeing 737-376

Approaching top of descent, the crew became aware of deteriorating weather conditions from the ATIS and from on-board weather radar as well as visual observations. The deteriorating weather was not forecast in the Darwin terminal area forecast (TAF). Fortunately, the aircraft was carrying sufficient fuel for one approach to Darwin and a diversion to Tindal, where weather conditions were fine. The crew became visual in heavy rain near the minima of the instrument approach at Darwin and landed without incident. At no stage did the crew receive a hazard alert, or advice from the company dispatch office regarding the changes in Darwin's weather conditions.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather at the destination landing minima.

6 COMPARISON OF ACCURACY OF TERMINAL AERODROME FORECASTS WITH TREND TYPE FORECASTS

All of the TAFs in this study came from airports with a Category 1 TAF service. A Category 1 TAF service has forecasts issued by the Bureau of Meteorology at least 6 hourly, valid for 18 or 24 hours, with a continuous meteorological watch and amendment service.

A TTF is also often provided at major airports. In effect, it is a forecast that is suitable for making an assessment about landing, which is issued more frequently than a TAF, but with a shorter period of validity. A TTF is defined as an aerodrome weather report to which a statement of trend is appended. The TTF relates to the weather conditions expected to affect the aerodrome for 3 hours after the time of the report.[6]

If a flight is to a destination that has a Trend Type Forecast (TTF), then the TTF supersedes the TAF as the forecast that should be used for assessing destination weather during its 3-hour validity period. Ten of the 13 airports in this study were serviced with TTFs.

The requirement to use a TTF in preference to a TAF if one was available was considered to imply an expectation of a higher level of forecast confidence in TTFs, because of their shorter period of validity and more frequent updates. This hypothesis was tested by comparing the frequency of potentially unsafe below landing minima events predicated on TAFs with a 2-hour time offset, with the frequency of potentially unsafe below landing minima events predicated on TTFs with a 2-hour time offset.

200101142 Boeing 767-238

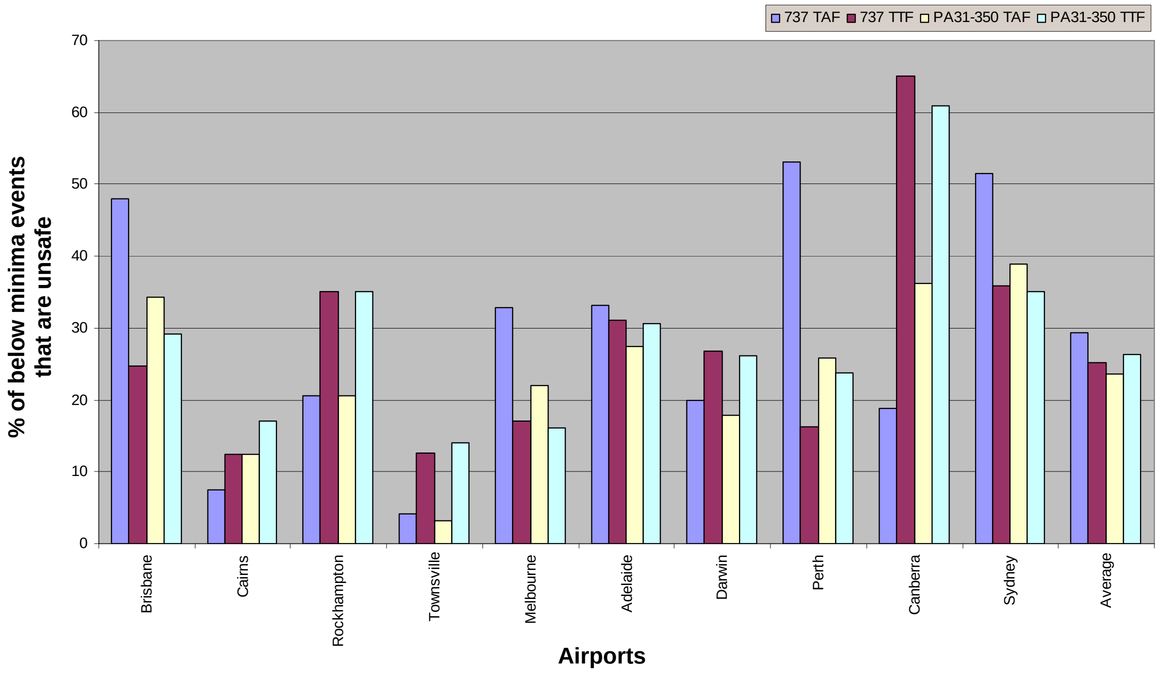
Due to the weather at the destination aerodrome being worse than originally forecast, the crew was required to divert to a nearby alternate aerodrome with weather contrary to forecast conditions. Consequently, the aircraft landed with less than minimum operational requirements.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather below the destination landing minima.

[6] AIP General 3.5.3.4.2, 25 November 2004.

Figure 5: Comparison of frequency of potentially unsafe below landing minima events between TAFs and TTFs



The forecast reliability between TTFs and TAFs varied among airports, and no consistent trend could be identified. TAFs gave a better performance than TTFs in half of the airports surveyed. Although it would appear intuitively logical to predicate operational decisions on a forecast type that predicts less far into the future, the data did not provide consistent evidence to support this approach at all airports.

200100216 Boeing 747-438

Air traffic control advised the crew of the Boeing 747, VH-OJN, that holding would be required due to unforecast severe weather at Brisbane. The aircraft was inbound to Brisbane from Auckland, and carried insufficient fuel to divert. The crew advised the controller they had sufficient fuel to hold for 50 mins. The aircraft commenced holding at FL210 in the vicinity of position DOLFN, 40 nm to the east of Brisbane. After 20 minutes, the controller instructed the crew to continue tracking the aircraft towards Brisbane, where it subsequently landed without further incident.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather above the destination landing minima after a delay.

7 OPERATIONAL DEFENCES

The requirements for weather-based decisions on the carriage of extra fuel to fly from the destination to an alternate described earlier are only applicable for pre-flight planning purposes. Once an aircraft is flying, the rules for carrying fuel to meet weather-related alternate diversion requirements do not apply, as it is not normally possible to refuel in flight. Allowances for this risk exist in conservative rules that provide a margin at the planning stage to provide for some inaccuracy in a weather forecast. This risk may be further mitigated if a pilot monitors a destination's weather information while en-route, and elects to divert in flight to another aerodrome if the destination's weather deteriorates.

The number of alternatives for diverting is dependent on the number of suitable alternate aerodromes in the vicinity and the flight range available at the time of diverting. In general, the later the decision to divert, the fewer alternatives remain available, because the aircraft has less fuel remaining. Also, in many cases, after a certain point the aircraft may have no option to divert at all, because it does not have sufficient fuel remaining to do so.

As a flight nears its destination, weather forecasting for the estimated time of arrival (ETA) may become more accurate. If this is true, the risk enhancement from the reducing opportunities to divert to an alternate may therefore be considered to be moderated by the increasing accuracy of weather information available to the flight crew, giving them greater confidence in information about their need to divert. As an example, shortly before landing a pilot will communicate with an air traffic controller in the control tower, who can describe what he can see in front of him, providing very up to date weather information. Effective use of weather updates is described and analysed in the next section.

7.1 En-route defences

It is normal procedure for a pilot who is flying to a destination with marginal weather conditions to be monitoring the destination weather as the time approaches when the option to divert to an alternate ceases. This is usually as the aircraft approaches the point from where it no longer has the range to fly to its last available alternate. Timely monitoring could enable a pilot to divert to a safe alternate if the weather appeared likely to deteriorate below the destination's landing minima.

Discussion with 737 operators indicated that an opportunity to divert almost always existed in Australia until the aircraft commenced its descent to its destination. On that basis, the usefulness of en-route weather monitoring as an effective risk mitigant was tested by considering the best available en-route destination weather information to assist in making decisions for a timely diversion. This was done by assessing destination weather reports[7] 30 minutes and 60 minutes before the ETA for all the unsafe events identified in this study. This information was used to determine the frequency of opportunities for a pilot to make a timely diversion on the basis of en-route weather reports. The test assumes that if a weather report indicated destination weather below the landing minima, the flight could then be diverted to a safe alternate.

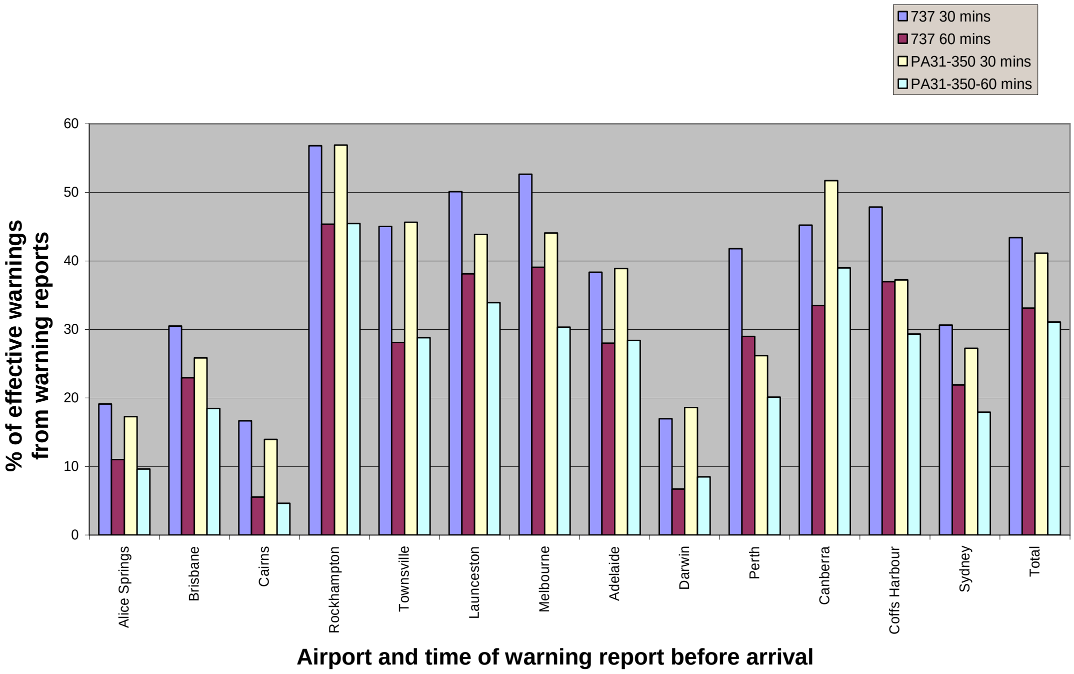
The test only measures the effectiveness of en-route weather updates as a risk mitigant by providing relevant information to help decision-making; it does not ensure or assume a safe outcome.

---

[7] A weather 'report' is a report of actual weather conditions, and provides no future predictions of weather, unlike a weather forecast.

Weather reports were used in preference to weather forecasts for this test, as receipt of a marginal weather report shortly before landing at a destination is likely to alert a pilot to the possibility of a need to divert, regardless of whether a forecast is also provided. The data available for this study were also more complete for weather reports than for TTFs; therefore weather reports were used to provide more complete data. The test algorithm is described in Appendix A, part 3.

Figure 6: Percentage of 'unsafe events' for which destination weather reports 30 minutes or 60 minutes before ETA provided a timely warning



The results show that approximately one third to one half of all unsafe events were likely to have received a timely warning in the form of destination weather reports that indicated that the weather was below landing minima. The exceptions were Alice Springs, Cairns and Darwin, where a significant fraction of below minima events were thunderstorm related, and such weather phenomena tend to be short-lived. Although there was likely to be less probability of an effective warning at these airports, the generally transient nature of the operationally limiting weather also meant that there was a higher probability that the weather would be above landing minima a short time after arrival, requiring only a short delay before landing.

200002800 DHC-8-102

The aircraft was required to divert to an alternate aerodrome due to weather conditions. However, at the alternate aerodrome, the cloud base was actually 1,000 ft lower than forecast. The crew conducted an NDB approach and landed without further incident.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather at the destination landing minima.

8 RATES OF UNFORECAST WEATHER-RELATED SAFETY OCCURRENCES THAT WERE REPORTED TO THE ATSB

The described statistical assessments provide an indication of the frequency with which the forecasting service may have presented an opportunity for a flight to become unsafe. Other defences may also have come into play in unforecast below landing minima weather. An assessment of some other possible defences was made by reviewing the ATSB accident and incident database for all occurrences when an unforecast weather change had been reported to be of safety relevance.

All reported instances of an incident or an accident associated with an unforecast deterioration of weather conditions at the destination were assessed for occurrences between 01 January 1996 and 31 December 2004.

A total of 62 occurrences were reported that were assessed as being of safety significance due to unforecast weather degradation. A number of operational defences may be available to a pilot in these circumstances to reduce the likelihood of an accident. The defences that were used in each occurrence were counted and are listed in Table 2. Some occurrences had more than one defence.

Table 2: Defences in reported unforecast weather occurrences in Australia, 1996 to 2004

Defence	Number	Explanation
No requirement broken		
Landed above landing minima	24	Weather deteriorated from above alternate minima before flight to above landing minima at the destination
Landed on the landing minima	9	Weather deteriorated from above alternate minima before flight to the landing minima at the destination
Defence used		
Held for weather improvement	12	Remained flying at the destination until the unforecast weather improved enough to enable a safe landing
Diverted before reaching destination	3	Diverted to an alternate aerodrome after receiving a weather forecast update en-route
Diverted after reaching destination	11	Diverted from the destination to an alternate aerodrome after an unforecast destination weather degradation
Exceeded a requirement		
Landed below weather minima	9	Landing conducted at the destination after the weather deteriorated from above alternate minima before flight to below landing minima at the destination
Consumed fuel reserve before landing	7	The aircraft landed with less than the required reserve fuel on board because of a weather-related delay in landing
Risk enhanced		
Accident	1	The weather conditions prevented a safe landing, and an accident ensued.

9 ALTERNATIVE METHODOLOGIES

9.1 Different criteria for weather alternate requirements

Australian rules have been used for the assessment in this study; however other countries use different rules and practices for assessing the need to carry fuel for an alternate aerodrome.

9.1.1 International rules

A set of rules has been compiled, based on a composite of the alternate requirements from the United States (US), the United Kingdom (UK) and New Zealand (NZ), described for the purposes of this study as the 'composite international' rule-set. The rule-sets used to compile the composite international rule-set are presented in Appendix B. The composite international rule-set has been used to provide a comparison with the results derived from the use of Australian rules. The composite international rule-set comprised a destination weather forecast with:

- no more than 4 oktas of cloud below a height of 2,000 ft above the airport,
- a minimum visibility of 5km,
- the crosswind limit not exceeded, and
- no thunderstorms forecast.

The populations of events when the weather was below the landing minima were compared with the respective forecasts at a 4-hour offset, assessed against the composite international rule-set and the Australian rule-set. This comparison showed which rule-set provided better protection to a pilot against the risk of an unforecast unsafe landing. Only a 4-hour time offset was considered.

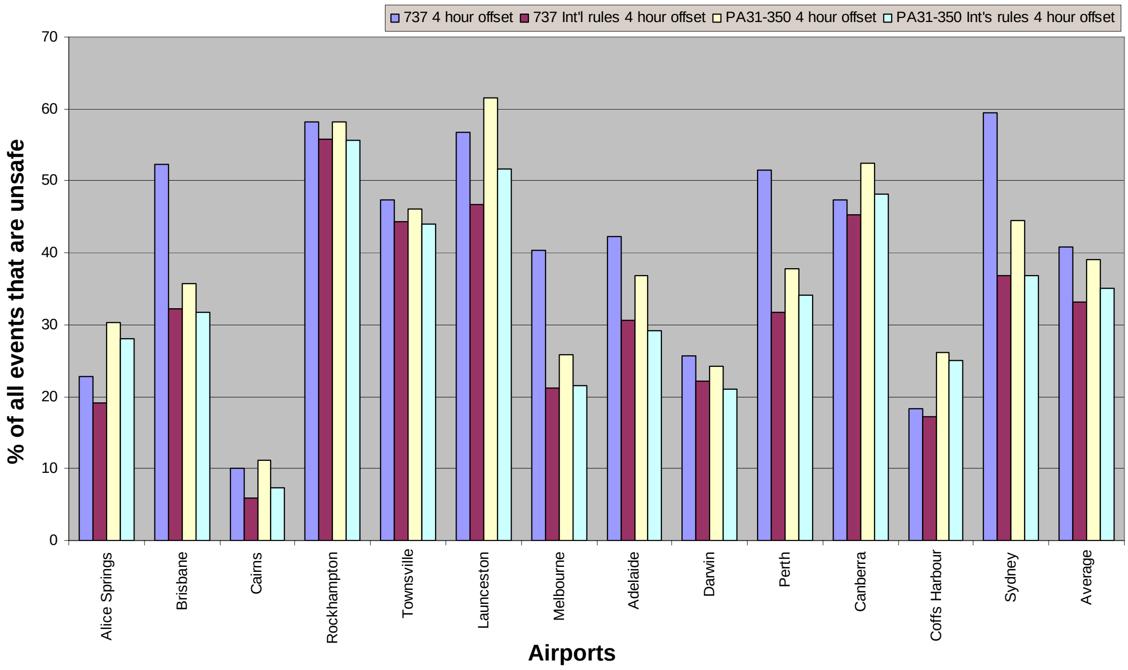
200006476 PA-31-350

The pilot reported that he encountered unforecast low cloud on arrival. During an instrument approach, visual reference with terrain was established, but the aircraft was not carrying sufficient fuel to divert to any alternate aerodrome.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather above the destination landing minima, but without carrying enough fuel to enable diversion to an alternate destination.

Figure 7: Fraction of below-minima events that were not predicted by forecasts at and a 4-hour offset for airports and aircraft types, assessed against the Australian rule-set and the 'composite International' rule-set



A comparison between Australian and composite international rule-sets provided broadly similar results. The more conservative alternate requirements from the 'composite international' rule-set provided a visible, but incremental, improvement in forecast reliability for 737 aircraft at Brisbane, Melbourne, Perth and Sydney, compared with the Australian rule-set that also included the ability to use special alternate minima for the 737s, (but not for the PA31-350),which would have allowed the 737 to be able to depart for a destination without carrying alternate fuel in worse weather than the PA31-350. These improvements did not provide the orders of magnitude in improvement that would have been required to meet the ICAO expectations as described in Section 2.

9.1.2 Mandatory carriage of fuel for an extra alternate

Operational decisions on the carriage of fuel to enable flight to an alternate airport are also affected by the nature of the operating environment. As an example, operations in northern Europe involve higher frequencies of inclement weather, and the existence of many more airports that are available for diversions. Both of these factors make the carriage of alternate fuel in Europe more likely than in Australia.

Anecdotal evidence from European pilots, from private to airline level, who were interviewed as a part of this study stated that all aircraft operations always carry fuel to fly to at least one alternate, irrespective of the forecast or actual weather conditions. Modelling this method of flight planning rapidly becomes complex when considering the options available when fuel to fly to an alternate is always carried. Two sample flights were selected to provide an indication of any safety enhancement afforded by always carrying fuel for both a destination and an alternate that were both above their respective alternate minima at the flight planning stage. The flights were chosen to provide the minimum choice of alternate options from the destination, to reduce the potential complexity in modelling the flight.

‘Double below landing minima’ events occurred when the weather on arrival at the destination was below landing minima, and after an appropriate time offset to allow for the aircraft to fly to the alternate, the weather at the alternate was also below landing minima. A ‘potentially unsafe event’ for any double below landing minima event was considered to exist if forecasts for both the destination and the alternate indicated that they would be above their respective alternate weather minima at the time of a four hour time offset for the destination. The algorithm for this test is described in greater detail in Appendix A, Part 3.

Table 3: Number of events when both destination and planned alternate were below landing minima for specific destination and landing pairs

	Aircraft	Number of ‘ ‘potentially unsafe’ events including ‘potentially unsafe’ alternate	Number of double below landing minima events
Unsafe YBCS then YBTL	737	0	3
	PA31-350	0	6
Unsafe YPAD then YMML	737	0	1
	PA31-350	0	4

The results considered the whole data set of TAF weather forecasts and weather reports for the destination airports. The frequency of both the double below landing minima events and the potentially unsafe events was considered to be very low. Although the numbers were too low to allow meaningful analysis, they were clearly much lower than the numbers of potentially unsafe events derived from other rules described in this study that were used to determine the need to carry fuel to fly to an alternate.

200002366 Boeing 767-338ER

While enroute, the pilot received an updated weather report for the destination airport. This required reserve fuel for the duration of the weather update. The pilot elected to continue as planned because fuel on board was sufficient to meet the holding requirement. When on descent, ATC advised that weather had deteriorated and additional holding reserve was required. The pilot informed ATC that the aircraft did not carry the additional reserve and that the Latest Point of Safe Diversion had been passed. The aircraft later landed without further incident.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather above the destination landing weather minima, but without carrying enough fuel to enable a diversion to an alternate destination.

10 DISCUSSION

10.1 Relevance of operational requirements to risk

Below landing minima events, as derived from assessing half-hourly weather reports against landing minima, happened between 0.4 per cent and 2 per cent of the time at various major airports.

Potentially unsafe events, as defined by comparing below landing minima events with their corresponding forecasts 2 hours and 4 hours before the event, and determining whether the forecast indicated above alternate minima weather, happened between 0.1 per cent and 1.2 per cent of the time at various major airports.

ICAO expects safety-critical operational ‘failure conditions’ that can affect continued safe flight and landing in air transport operations to be designed to create a maximum risk in the order of 1 millionth of 1 percent.

The frequency of potentially unsafe events as defined in this study does not correspond with the expectations of reliability for safety-critical aspects of air transport operations. However, the number of reports received by the ATSB of significant weather-related occurrences on landing are much lower than the frequency of unsafe outcomes that could be predicted from this study on unforecast deteriorated weather at landing.

10.2 Risk mitigants

It is possible that other risk mitigants are effectively reducing the risk. The classes of mitigant that have been considered are:

- A requirement that extra fuel is always carried that always enables a diversion from the destination to at least one alternate.
- Events when an adequate warning is received en-route to enable a timely diversion if the weather deteriorates at the destination.
- An expectation that aircraft are capable of landing safely (or with low risk) in below landing minima weather conditions.

Mandatory extra alternate fuel

The requirement to always carry fuel to fly to at least one alternate was tested, and demonstrated a marked increase in safety. However, the numbers of events that met the criteria were sufficiently low that it was not possible to make any statistically significant analysis beyond stating that this requirement does create a significant reduction in risk.

The Australian operating environment is different from many parts of the world where a similar operational requirement is used, both because of its more benign operating environment, and because of the larger distances than normally exist between suitable alternate airports. These factors could both reduce the perceived need to make a requirement for the mandatory carriage of fuel for an extra alternate, and to make such a requirement more onerous with a greater fuel uplift.

En-route weather updates

This study's test of warnings provided by en-route weather updates indicated that while they can provide an incremental risk reduction, they rarely provide an effective warning for more than 50 per cent of potentially unsafe events at any particular airport, as defined for this test. This reduction is observable and can be measured, but it is 'incremental' when compared with the orders of magnitude in risk reduction that would be required to meet the safety expectations described in Section 2.

Ability to land in below landing minima weather

Most large airline aircraft operating today in Australia carry sophisticated equipment that could facilitate a landing in worse weather than the landing minima at many airports. This equipment includes flight management systems, multiple autopilots and complex automation. However, the equipment at Australian airports does not support the reliability required to enable a safe landing at such very low weather minima, so although it would be possible to land in many cases, there would also be an increased risk. Smaller aircraft like the PA31-350 do not normally have the same level of sophistication in navigation equipment and automation, thereby reducing the effectiveness of this factor as a risk mitigator.

The relevance of special alternate minima as a risk mitigant in below landing minima weather

The use of 'special alternate minima' rules permits the crew of a suitably equipped aircraft to plan to fly to a destination without carrying the additional fuel required to fly to an alternate even if the destination forecast is somewhat worse, at the flight planning stage, than the normal alternate weather minima criteria. This means that there is a smaller margin between the alternate weather minima criteria used for planning the flight and the landing minima criteria, which are used at the time of landing.

This means that there is a greater probability that an aircraft operating to special alternate minima weather criteria will arrive at a destination with below landing minima weather criteria and without sufficient fuel to divert to an alternate. In such a circumstance, the instrument duplication required for the use of special alternate minima will not mitigate the risks inherent associated with landing in below landing minima weather.

Instrument duplication does not therefore act as a risk mitigation for landing in weather below landing minima, when the probability of that event increases by the use of special alternate minima associated with that instrument duplication.

Combined effect of supplementary risk mitigants

The mandatory, permanent carriage of extra fuel would provide a significant reduction in risk. The use of en-route updated weather warnings would provide an incremental reduction in risk. The reduction in risk associated with enhanced aircraft capabilities to land in deteriorated weather varies with the type of aircraft; however, the risk will be increased if the ground facilities and infrastructure have not been enhanced to ensure a safe landing at lower minima associated with those enhanced aircraft capabilities.

Recent Australian accident history indicates a very low frequency of significant incidents or accidents associated with unforecast destination weather; at least a lot lower than a rate that would be predictable from the results of this study. It is therefore reasonable to assume that other factors are reducing the probability of weather related landing occurrences. Some risk mitigators have been discussed above, but it is unlikely that they are the only mitigators.

It is likely that pilot skill and experience in making appropriate decisions also provide a significant contribution to risk mitigation. However, the extent of this contribution has not been assessed.

The mitigators described above are generally not prescribed, regulated or managed, although they appear to be presently effective. As they are not consistently controlled, it is hard to make an individual or a collective quantitative assessment of their effectiveness, and it is therefore difficult to be confident about the continued effectiveness of the processes in place today to ensure that an aircraft does not arrive at an airport with insufficient fuel to meet an operational need to divert to an alternate.

200002305 Boeing 767-238

Prior to the top of the descent, the crew monitored the automatic terminal information service, which indicated low mist patches in the aerodrome area. The approach controller indicated to the crew that fog was rapidly obscuring both runways. However, the tower controller indicated that the visibility on runway 21 was 800 metres. At the minimum descent altitude, the crew reported to the tower controller that they had visual contact with the runway. The crew later reported that during the landing roll, visibility reduced to less than 600 metres.

The current terminal area forecast indicated fog 6.5 hours after the aircraft was due to land, while the aerodrome trend type forecast indicated periods of reduced visibility to 4,000 metres for 30 minutes of less.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather at the destination landing weather minima.

11 CONCLUSION

Aircraft accidents associated with IFR flight into unforecast deteriorated weather at the destination are very rare. The effectiveness of the procedures that exist to ensure that a pilot does not encounter unforecast deteriorated weather at the destination does not explain the associated lack of accidents, but other risk mitigators are probably proving effective. It is possible that conservative decision making by flight crews, consuming fuel reserves to reach an alternate and conducting successful instrument approaches in weather conditions that are below landing minima are some of the mitigators that have been effective. However, these mitigators have not been assessed in this study.

199906031 Boeing 737- 376

On the basis of the weather forecast that was available prior to departure from Perth, the crew of B737, VH-TAW had planned to arrive at Melbourne without extra fuel. The crew received weather reports during the flight indicating that the weather at the destination was worse than forecast. On arrival at Melbourne, the weather was found to be such that there was a requirement for the aircraft to be carrying extra fuel. The aircraft landed without incident at 11:34 eastern summer time.

The Bureau of Meteorology reported that at the time of the occurrence a high pressure system was located in the Great Australian Bight. This resulted in a moist southerly airstream being directed over Victoria. However the low cloud, showers and drizzle associated with the moist airstream were expected to clear by mid to late morning because of drier air moving into the area from the south. The arrival of the drier air was later than anticipated, and reduced visibility in drizzle fluctuated around the alternate minima until 13:00 hours. The forecaster, being aware of the operational impact of his decisions, considered that a trend of INTER was sufficient to cover these fluctuating conditions. However, between 11:00 and 13:00 conditions were below the special alternate minima. The timing of the arrival of the drier air was critical in the situation. Unfortunately, neither the data network nor the forecasting skills were adequate to facilitate forecasting of a cloud base to within a couple of hundred feet when the cloud base was fluctuating around the alternate minima. The Bureau of Meteorology advised that it would have been more prudent to trend alternate conditions until there was clear evidence that the drier air had reached the airport. Following the occurrence, the Bureau of Meteorology issued a recommended preventative action to prevent further recurrence

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft landed in weather above the destination landing minima.

12 GLOSSARY

Weather forecast:	A prediction of future weather conditions for a defined period of time for a defined atmospheric volume.
Weather report:	A report in a predefined format of observations of meteorological conditions at an aerodrome at a defined time.
Observations:	Observations of specific weather phenomena at an aerodrome at a defined time that will be collated into a weather report.
Landing weather minima:	The defined minimum meteorological conditions under which a visual segment of an instrument approach procedure may be initiated to continue an approach to land.
Alternate weather minima:	The defined minimum meteorological conditions for an aerodrome below which, when forecast, require an aircraft to carry extra fuel enabling it to continue a flight to an alternate aerodrome that does not itself have any alternate requirements.
Cloud base:	The height above which the ground is obscured by cloud for more than half the time
Visibility:	A measure of the opacity of the atmosphere, the greatest distance one can see objects with the unaided eyesight.
Crosswind:	The vector component of the actual wind that acts across the direction of a specific runway.
Downwind:	The vector component of the actual wind that acts parallel to, and in the landing direction on a specific runway.
Altitude:	Vertical distance above mean sea level, measured in feet.
Height:	Vertical distance above the ground, measured in feet.

199904299 PA-31

The forecast for the destination indicated that the pilot would be able to conduct a visual approach to land; however, there was unbroken cloud over the airfield when the aircraft arrived at the destination. The pilot conducted a number of instrument approaches before he was able to land.

The investigation revealed that the forecast was for a cloud base of 2,000 ft. The actual base was 600 ft. The cloud base lifted during the time that the pilot conducted the instrument approaches.

ATSB Summary

Following an unforecast weather deterioration at the destination, the pilot sunsequently landed the aircraft in weather at the destination landing weather minima, after a delay.

13 APPENDIXES

13.1 Appendix A: Test algorithms

13.1.1 Part 1

Algorithm logic for assessing the safety to IFR aircraft from using weather forecasts for specific airports.

The algorithm is a multi step process.

- A data set of meteorological forecasts and reports was obtained from the Bureau of Meteorology, sorted by time and location, and cleansed.

- Each remaining recorded weather observation was then compared with the landing minima available from the instrument approaches at the airport concerned. If the weather was worse than the landing minima on all available approaches, the conditions were considered to be 'potentially unsafe for landing'. The recorded weather observation was then discarded from the study population if it was considered to be safe for a landing. The remaining study population formed the 'potentially unsafe for landing' study population.

- Forecasts were then sought to correlate with each of the recorded weather observations from the 'potentially unsafe for landing' study population for the destination airport in question. To find the appropriate forecast, the time that flight planning would have been taking place was calculated by subtracting a time offset from the time of the 'potentially unsafe for landing' observation. The most recently issued forecast for the appropriate aerodrome at this time was used for comparison. If there was no valid forecast, then the below-minima event was not counted when calculating the frequency of potentially unsafe below landing minima events. Each of these forecasts was then compared with the alternate minima for that airport's approaches which were available to that aircraft type. The comparisons considered the 30-minute buffers associated with INTER, TEMPO and FM for TAFs[8], but not for TTFs (a 60-minute buffer was used with the composite international rule-set described in Appendix A, part 2). If there was an instrument approach available where the forecast weather was better than the alternate minima criteria, then the forecast was considered to be predicting safe conditions. This was then counted as a 'potentially unsafe event', and formed one of the 'potentially unsafe event' study population.

---

[8] For details on the use of INTER, TEMPO an FM; see Aeronautical Information Publication ENR 1.1.72.2, issued 25 November 2004.

Criteria for comparison of reported observed weather conditions with landing minima

The following questions were incorporated in the data-selection algorithm for defining a weather report as being below the landing minima:

- Were thunderstorms present? ➔ if YES, count as below landing minima,
    - was 'TS' included in the significant weather section of a METAR/SPECI.

OR

- Was the crosswind limit for the aircraft exceeded? ➔ If YES, count as below landing minima,
    - was rain included in significant weather? ➔ if YES, was runway grooved ➔ if NO, use wet runway crosswind limit
    - ELSE, use dry runway crosswind limit.

OR

- Was the cloud base below the landing minima? ➔ if YES, count as below landing minima.
    - Add cloud layers from the lowest height, based on AIP ENR - 72.2.1 (issued 25 November 2004), and then find lowest altitude where BKN or more cloud exists.

OR

- Was the visibility below landing minima? ➔ if YES, count as below landing minima.
    - If the visibility was endorsed with a direction, the higher visibility in the report was assessed. The requirements for directional visibilities are described at the end of this Part.

If there were no approaches available for that airport at that time, for which the observed weather was above the respective landing minima, then the conditions were considered to be **'potentially unsafe for landing'**.

Criteria for comparison of forecast weather with Alternate Minima

The algorithm for assessing a forecast against the alternate minima criteria was the same as the one for assessing a weather report against the landing minima criteria, but the criteria themselves were different, as the alternate weather minima were used instead of the landing weather minima. The following criteria were assessed:

- Are thunderstorms forecast?
- Is the crosswind limit for the aircraft forecast to be exceeded?
- Is cloud ceiling forecast below the alternate minima?
- Is visibility forecast below the alternate minima?

If there was at least one approach where the forecast predicted all of the criteria to be above the alternate minima, then the forecast was considered to be predicting safe conditions. A report that was considered 'potentially unsafe for landing' AND its forecast with the corresponding time offset that was considered to be forecasting 'safe landing' combined to form a **'potentially unsafe event'**.

Justification for approach to directional visibility reports

Reports only have a directional visibility appended after the first visibility if:

- The appended visibility covers less than half the sky, in a general direction.
- The appended visibility is less than 2/3 the visibility for the remainder of the sky
- The appended visibility is less than 5000 metres.

13.1.2 Part 2

Applying the 'composite international' rule-set to Australian weather conditions

A composite of the foreign rules described in Appendix B was applied to the weather data, to provide a comparison with the risk associated with inadequate weather-related alternate predictions when using the Australian rule set. The composite international rule-set was generally more conservative than Australian requirements for destination alternate minima; only one approach had more destination alternate minima that required a higher capability under the composite international rule-set. The algorithm described in appendix A, part 1 was applied using the composite international rule-set, but with a consistent use of destination alternate minima requirements of:

- No more than 4 oktas cloud below 2,000 ft height
- No less than 5,000 m visibility
- Standard operational crosswind and downwind limitations
- No forecast of thunderstorms
- A 60-minute buffer on INTER, TEMPO and FM criteria at the destination airport.

The results are presented and discussed in Figure 7

13.1.3 Part 3

Mandatory extra alternate airport requirement

The alternative informal fuel requirement methodology that was frequently described for use in Europe was also tested.

The options are more complex when planning for a flight for which fuel to fly to an alternate must always be carried, as more alternative flight planning options exist. For this reason, a limited number of predefined flights have been considered, rather than considering destination airports alone.

Planned flight routes considered for the test

- Destination of Cairns, with Townsville as an alternate
  (An assumption of 30 minutes for the 737 to fly from Cairns to Townsville, and 60 minutes for the PA31-350).

- Destination of Adelaide, with Melbourne as an alternate
  (An assumption of 60 minutes for the 737 to fly from Adelaide to Melbourne, and 120 minutes for the PA31-350).

Criteria for a 'double below-minima' event and a 'potentially unsafe event'

- Were the weather conditions at the destination at the time of landing below landing minima?

  ➔ if YES, allow a time offset to fly from the destination to the alternate airport. At that offset time, were the weather conditions at the alternate airport below landing minima?

  ➔ if YES, That event is considered as a '**double below landing minima'** event.

Then, for all double below landing minima events:

- Was the destination weather forecast for the time of landing at the destination that was issued with a four hour time offset from the time of landing at the destination, above alternate minima?

  ➔ if YES, was the alternate weather forecast for the time of landing at the alternate that was issued with a four hour time offset from the time of landing at the destination, above alternate minima?

  ➔ If YES, That event is then considered as a **'potentially unsafe event'**.

For the purpose of this test, double below-minima events may therefore be considered as either safe or potentially unsafe, with potentially unsafe events being a subset of double below-minima events

200001238 DHC-8-102

On arrival in the circuit area at the destination, the crew had difficulty in establishing visual reference due to the actual weather conditions being at variance with those forecast.

ATSB Summary

Following an unforecast weather deterioration at the destination, the aircraft subsequently landed in weather below the destination landing minima.

13.1.4 Part 4

Assessment of en-route weather updates as a risk mitigants

All the 'potentially unsafe events' identified using a weather forecast with a 4-hour offset were compared with the destination's weather reports at 30 minutes and 60 minutes before the estimated time of arrival (ETA). If the weather report indicated that the destination weather was below the landing minima, then this was considered to be an effective risk mitigant, in that it provided information to the flight crew to alert them to the weather-related risk at the destination in sufficient time to increase the chance of a safe diversion to an alternate airport.

Criteria for effective risk mitigation from weather updates:

Was the weather at the destination the time of landing below landing minima?

- ➔ if YES, did the forecast with the appropriate time offset predict that the weather would be above the alternate minima?
- ➔ if YES, was the destination weather report 30/60 minutes before ETA below landing minima?
- ➔ if YES, then the destination weather report 30/60 minutes before ETA was considered as an **effective risk mitigant**.

13.1.5 Part 5

Comparison of potentially unsafe events predicated on TAFs compared to TTFs

The population of TTFs available for this study was smaller than the populations of TAFs and weather reports. All the below landing minima events identified from the weather reports were checked for a corresponding TTF with a 2-hour time offset. If there was no corresponding TTF, then that below landing minima event was not used for this test. The below landing minima event was then assessed against the corresponding TTF and the corresponding TAF with a 2-hour time offset, to provide a frequency of potentially unsafe below landing minima events as described in Appendix A, part 1. The corresponding frequencies of potentially unsafe events as predicted by TTFs and TAFs with a 2-hour time offset are presented at Figure 5.

199901586 Saab SF-340A

The crew reported that the actual weather at Wagga Wagga was significantly worse than had been forecast. After carrying out two instrument approaches, and failing to become visual on each occasion, they diverted to Albury where a successful instrument approach and landing was made. When they returned to Wagga Wagga 1½ hours later, the crew reported the actual conditions were still below the alternate minima requirement despite the TAF indicating an improvement in conditions from 1000 EST.

ATSB Summary

Following an unforecast weather deterioration at the destination, the flight crew subsequently diverted the aircraft to an alternate destination.

13.2 Appendix B: Domestic and international rules for weather alternate requirements

Table 4: Outline of international requirements for a flight not carrying fuel to fly to an alternate from the destination

	ICAO	**Australia**	**USA**	**New Zealand**	**UK- UK registered aircraft**
Reference documentation	ICAO Annex 6 to the Convention on International Civil Aviation Organization.	Australian Aeronautical Information Publication	Federal Aviation Regulation 121.615	New Zealand Aviation Rules Part 91.405: General operating and flight rules	JAR-OPS 1.295 (c)
Alternate weather minima	Notes: *"It is the practice in some States to declare, for flight planning purposes, higher minima for an aerodrome when nominated as a destination alternate than for the same aerodrome when planned as that of intended landing."*	Alternate aerodrome minima is either: • Specified in the departure and approach procedure documents for each aerodrome and approach procedure; • For any aerodrome without an approach procedure, the alternate minima 500 ft above LSALT for final route segment and a visibility of 8 km.	Alternate aerodrome not required if the weather forecast for the destination indicates weather minima of: • cloud ceiling is at least 2,000ft height • visibility is greater than 3 miles (5,560 metres).	Alternate aerodrome not required if the weather forecast for the destination indicates weather minima of • cloud ceiling at the aerodrome will be at least 1000 ft above the prescribed landing minima • visibility of at least 5km or 2km greater than the prescribed minima whichever is greater.	Alternate aerodrome not required if the weather forecast for the destination indicates weather minima of : • cloud ceiling at the destination aerodrome at least 2,000 ft height or circling MDA +500ft • visibility of at least 5km.
Destination alternate aerodromes	An IFR flight must have at least one destination alternate aerodrome specified in the flight plan unless: • for the duration of the flight the meteorological conditions at the destination aerodrome for a reasonable period before and after the ETA are above the minima required for the approach and landing to be made under VMC; or • if there is no suitable alternate aerodrome.	An alternate aerodrome must be specified in the flight plan if weather is below the minima specified for the destination aerodrome from 30 minutes before the ETA or 60 minutes after. An alternate aerodrome must not itself require an alternate.	The destination and alternate aerodromes must have forecasts that are valid from 60 minutes before the ETA to 60 minutes after.	An IFR flight must list at least one alternate aerodrome in the flight plan unless the destination aerodrome has a standard instrument approach procedure and, at the time of submitting the flight plan, the meteorological forecast indicate for at least 1 hour before and after the ETA weather at the destination aerodrome is at or above specified minima.	An IFR flight must identify at least one alternate aerodrome unless the destination has two useable runways, and a forecast valid for at least 1 hour before and after the ETA. The flight must be less than 6 hours duration. Special rules apply for flights to aerodromes where alternates are not available such as remote islands.

13.2.1 ICAO requirements

Annex 6 — Operation of Aircraft (1998)

4.3.4.3 *Destination alternate aerodromes*

For a flight to be conducted in accordance with the instrument flight rules, at least one destination alternate aerodrome shall be selected and specified in the operational and ATS flight plans, unless:

a) the duration of the flight and the meteorological conditions prevailing are such that there is reasonable certainty that, at the estimated time of arrival at the aerodrome of intended landing, and for a reasonable period before and after such time, the approach and landing may be made under visual meteorological conditions; or

b) the aerodrome of intended landing is isolated and there is no suitable destination alternate aerodrome.

4.3.5 Weather conditions

4.3.5.1 A flight to be conducted in accordance with the visual flight rules shall not be commenced unless current meteorological reports or a combination of current reports and forecasts indicate that the meteorological conditions along the route or that part of the route to be flown under the visual flight rules will, at the appropriate time, be such as to render compliance with these rules possible.

4.3.5.2 A flight to be conducted in accordance with instrument flight rules shall not be commenced unless information is available which indicates that conditions at the aerodrome of intended landing or, where a destination alternate is required, at least one destination alternate aerodrome will, at the estimated time of arrival, be at or above the aerodrome operating minima.

Note: It is the practice in some States to declare, for flight planning purposes, higher minima for an aerodrome when nominated as a destination alternate than for the same aerodrome when planned as that of intended landing.

199805218 A320-211

The pilot of an aircraft en route from Perth to Melbourne diverted to Adelaide due to deteriorated weather conditions in Melbourne. The aircraft was carrying insufficient fuel for an alternate.

ATSB Summary

Following an unforecast weather deterioration at the destination, the flight crew diverted the aircraft to an alternate destination.

13.2.2 Australian requirements

72. ALTERNATE AERODROMES [9]

72.1 General

72.1.1 A pilot in command must make provision for flight to an alternate aerodrome, when required, in accordance with the following paragraphs.

72.1.2 When a flight is required to provide for an alternate aerodrome, any aerodrome may be so nominated for that flight provided:

a. it is suitable as a destination for that flight; and

b. is not an aerodrome for which that flight would require to provide for an alternate aerodrome.

72.1.3 When an aerodrome forecast is not available or is 'provisional', the pilot in command must make provision for a suitable alternate that has a firm forecast.

72.2 Weather Conditions

72.2.1 Except when operating an aircraft under the VFR by day within 50NM of the point of departure, the pilot in command must provide for a suitable alternate aerodrome when arrival at the destination will be during the currency of, or up to 30 minutes prior to the forecast commencement of, the following weather conditions:

a. cloud - more than SCT below the alternate minimum (see paras 72.2.12 and 72.2.13); or
Note: In determining requirements for alternate aerodromes, fore-
cast amounts of cloud below the alternate minima are cumulative.
For determining requirements, the cumulative cloud amount is interpreted as follows:
FEW plus FEW is equivalent to SCT,
FEW plus SCT is equivalent to BKN,
SCT plus SCT is equivalent to BKN or OVC.

b. visibility - less than the alternate minimum; or

c. visibility - greater than the alternate minimum, but the forecast
is endorsed with a percentage probability of fog, mist, dust or
any other phenomenon restricting visibility below the alternate
minimum; or

d. wind - a crosswind or downwind component more than the maximum for the aircraft.
Note: Wind gusts must be considered.

72.2.2 When operating a helicopter under the VFR, and the use of helicopter VMC is permissible at the destination, the pilot in command must provide for a suitable alternate aerodrome when either of the following conditions is forecast at the destination:

a. cloud - more than SCT below a ceiling of 1,000FT; or

[9] See Aeronautical Information Publication ENR 1.1, issued 24 Nov 2005

b. visibility - less than 3,000M.

72.2.3 When weather conditions at the destination are forecast to be as specified at para 72.2.1, but are expected to improve at a specific time, provision for an alternate aerodrome need not be made if sufficient fuel is carried to allow the aircraft to hold until that specified time plus 30 minutes.

72.2.4 When weather conditions at the destination are forecast to be above the values specified at para 72.2.1, but, additionally, intermittent or temporary deteriorations in the weather below the values are forecast, provision of an alternate need not be made if sufficient additional fuel is carried to allow the aircraft to hold for:

a. 30 minutes for intermittent deterioration (INTER); and

b. 60 minutes for temporary deterioration (TEMPO).

72.2.5 When thunderstorms or their associated severe turbulence or their probability is forecast at the destination, sufficient additional fuel must be carried to permit the aircraft to proceed to a suitable alternate or to hold for:

a. 30 minutes when the forecast is endorsed INTER; or

b. 60 minutes when the forecast is endorsed TEMPO.

72.2.6 When a forecast has multiple INTER or TEMPO deteriorations and holding fuel will be carried, fuel must be carried to hold for only the most limiting requirement. INTER and TEMPO holding fuel requirements are not cumulative.

72.2.7 When TAFs include a FM period, during which time an operational requirement will either become effective or be removed, the timing for the change in operational requirement is as follows:

a. When the weather during the FM period is forecast to create an operational requirement, that operational requirement will become effective 30 minutes before the start of the FM time.

b. When the weather during the FM period is forecast to remove an operational requirement, that operational requirement will remain effective until 30 minutes after the FM time stated in the forecast that removes the operational requirement.

72.2.8 The additional fuel required by paras 72.2.4 or 72.2.5 must be carried when the ETA of the aircraft at its destination or alternate falls within the period 30 minutes before the forecast commencement time to 30 minutes after the expected time of cessation of these deteriorations.

72.2.9 Due to the continuous weather watch provided by TTF, the 30 minute buffers required by paragraphs 72.2.7 and 72.2.8 do not apply. Flights which will be completed within the time of validity of the TTF may be planned wholly with reference to the destination TTF.

72.2.10 TTF may have either one visibility or two visibilities included in the report. Operational requirements will apply when:

a. the sole visibility is less than the alternate minimum, or

b. the higher visibility is less than the alternate minimum.

72.2.11 Flights which cannot use TTF will plan the flight on the current TAF until such time as the destination ETA falls within the validity period of a TTF.

72.2.12 For IFR flights, the alternate minima are as follows:

a. For aerodromes with an instrument approach procedure, the alternate minima published on the chart (see ENR 1.5, Section 6.).

b. For aerodromes with an instrument approach procedure where an aerodrome forecast is unavailable or is “provisional”, the pilot in command must make provision for a suitable alternate.

c. For aerodromes without an instrument approach procedure, the alternate minima is the lowest safe altitude for the final .route segment plus 500FT and a visibility of 8KM (also refer ENR 1.10 sub-section 1.4).

72.2.13 For flight by aeroplanes under the VFR (day or night) and helicopters operating under the VFR at night, the alternate minima are a ceiling of 1,500FT and a visibility of 8KM.

For VFR helicopter operations by day, the alternate minima are the same as for night unless the additional conditions specified in ENR 1.2 para 2.6 are met. When these additional conditions are met, the alternate minima requirements are as shown in para 72.2.2.

13.2.3 US requirements

Attachment A: Federal Aviation Regulations

§ 121.619 Alternate airport for destination: IFR or over the top: Domestic operations

(a) No person may dispatch an airplane under IFR or over the top unless he lists at least one alternate airport for each destination airport in the dispatch release. When the weather conditions forecast for the destination and first alternate airport are marginal at least one additional alternate must be designated. However, no alternate airport is required if for at least 1 hour before and 1 hour after the estimated time of arrival at the destination airport the appropriate weather reports or forecasts, or any combination of them, indicate -

(1) The ceiling will be at least 2,000 feet above the airport elevation; and

(2) Visibility will be at least 3 miles.

(b) For the purposes of paragraph (a) of this section, the weather conditions at the alternate airport must meet the requirements of § 121.625.

(c) No person may dispatch a flight unless he lists each required alternate airport in the dispatch release.

[Doc. No. 6258, 29 FR 19222, Dec. 31, 1964, as amended by Amdt. 121-159, 45 FR 41594, June 19, 1980; Amdt. 121-253, 61 FR 2614, Jan. 26, 1996]

§ 121.625 Alternate airport weather minimums

No person may list an airport as an alternate airport in the dispatch or flight release unless the appropriate weather reports or forecasts, or any combination thereof, indicate that the weather conditions will be at or above the alternate weather minimums specified in the certificate holder's operations specifications for that airport when the flight arrives.

[Doc. No. 6258, 29 FR 19222, Dec. 31, 1964, as amended by Amdt. 121-33, 32 FR 13912, Oct. 6, 1967]

13.2.4 New Zealand requirements

Civil Aviation Rules, General Operating and Flight Rules, Part 91

91.405 IFR alternate aerodrome requirement

(a) A pilot-in-command of an aircraft operating under IFR must list at least one alternate aerodrome in the flight plan unless—

(1) the aerodrome of intended landing has a standard instrument approach procedure prescribed under Part 19; and

(2) at the time of submitting the flight plan, the meteorological forecasts indicate, for at least 1 hour before and 1 hour after the estimated time of arrival at the aerodrome of intended landing, that—

(i) the ceiling at the aerodrome will be at least 1000 feet above the minima prescribed under Part 19 for the instrument procedure likely to be used; and

(ii) visibility will be at least 5 km, or 2 km more than the prescribed minima, whichever is the greater.

(b) A pilot-in-command of an aircraft must not list any aerodrome as an alternate on the IFR flight plan under paragraph (a) unless the meteorological forecasts at the time of submitting the flight plan indicate that, at the estimated time of arrival at the alternate aerodrome, the ceiling and visibility at that aerodrome will be at or above the following meteorological minima—

(1) if an instrument approach procedure with alternate minima has been prescribed under Part 19 for the aerodrome, the specified alternate aerodrome minima for that instrument approach procedure; or

(2) the following minima—

(i) for a precision approach procedure, a ceiling of 600 feet, or 200 feet above MDA, whichever is the higher, and a visibility of 3000 metres, or 1000 metres more than the prescribed minima, whichever is the greater; and

(ii) for a non-precision approach procedure, a ceiling of 800 feet, or 200 feet above MDA, whichever is the higher, and a visibility of 4000 metres, or 1500 metres more than the prescribed minima, whichever is the greater; or

(3) if no instrument approach procedure has been prescribed under Part 19 for the alternate aerodrome, the ceiling and visibility minima prescribed under Part 91 Subpart D for VFR operation for descent below the minimum altitude for IFR flight prescribed under 91.423. (c) A pilot-in-command of an aircraft must not list any aerodrome as an alternate aerodrome in the IFR flight plan under paragraph (a) unless that alternate aerodrome is equipped with a secondary electric power supply for—

(1) the ground based electronic navigation aids necessary for the instrument approach procedure to be used; and

(2) aerodrome lighting for night operations.

13.2.5 UK requirements

JAR-OPS 1.295 (c)

(c) An operator must select at least one destination alternate for each IFR flight unless:

(1) Both:

(i) The duration of the planned flight from take-off to landing does not exceed 6 hours; and

(ii) Two separate runways are available and useable at the destination and the appropriate weather reports or forecasts for the destination aerodrome, or any combination thereof, indicate that for the period from one hour before until one hour after the expected time of arrival at destination, the ceiling will be at least 2 000 ft or circling height + 500 ft, whichever is greater, and the visibility will be at least 5 km. (see IEM OPS 1.295 (c)(1)(ii)); or

(2) The destination is isolated and no adequate destination alternate exists.

(d) An operator must select two destination alternates when:

(1) The appropriate weather reports or forecasts for the destination, or any combination thereof, indicate that during a period commencing 1 hour before and ending 1 hour after the estimated time of arrival, the weather conditions will be below the applicable planning minima; or

(2) No meteorological information is available.

199802763 A300-B4-203

The pilot reported that he departed Brisbane for Sydney with no weather related requirement for holding fuel. On arrival at Sydney the weather had deteriorated, and he became visual at the minima on a runway 34 left ILS.

ATSB Summary

Aircraft landed in weather at the destination landing minima following an unforecast destination weather deterioration.

199900782 EMB-120 ER

The pilot obtained a weather forecast by fax approximately one hour prior to departure that gave the destination aerodrome forecast of CAVOK indicating no operational requirements. The aviation routine weather report indicated showers in the vicinity of the destination; consequently the crew uplifted maximum fuel as a precaution.

Just prior to descent into Mt Isa, the pilot received an updated weather report indicating thunderstorms at Mt Isa. Active thunderstorms at the airfield were confirmed by contact with ground staff. A check with Brisbane FS confirmed that the aerodrome forecast of CAVOK was still current.

The pilot reported that they would not normally carry any unplanned extra fuel for holding or diversion and that an RPT aircraft landing at the time of the thunderstorm had made three rejected approaches prior to landing.

ATSB Summary

The crew had uplifted extra fuel on the basis of a non-aviation weather forecast, and the destination weather had deteriorated in line with that forecast.

199802764 Boeing 767-338ER

The pilot reported that the TAFOR Brisbane used for flight planning specified no requirements for Brisbane. A special weather report received ten minutes prior to arrival indicated 800 metres visibility in fog. The flight continued to Brisbane with Coolangatta as an alternate. The pilot was concerned that fuel carried for the flight may have been insufficient as a result of the inaccurate forecast, had a diversion been required.

ATSB Summary

Aircraft landed in weather at the destination landing minima following an unforecast destination weather deterioration.

13.3 Appendix C: Landing and alternate minima

Sorting methodology for landing minima

Instrument approaches for each airport were sorted so that the instrument approach that required the highest capability was given first preference. Subsequent approaches sequentially required the next highest capability, but using different runways, so that if there was a crosswind limit on the approach with the highest capability requirement, other approaches could be assessed, until all runways had been assessed. Each weather report was assessed against its airport's landing minima, and the report was only considered to be 'below landing minima' if it was not safe to land on any of the minima described below.

Table 5: Minimum destination weather conditions from which a safe landing may be made after conducting an instrument approach

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Alice Springs	737	1	12 ILS	115	0.8	214	30	23
		2	30 GNSS	295	2.3	317	30	23
	PA31-350	1	12 ILS	115	1.2	214	20	20
		2	30 GNSS	295	2.3	317	20	20
Brisbane	737	1	01ILS	16	0.8	207	30	23
		2	19ILS	196	0.8	207	30	23
		3	14VOR	134	3.2	587	24	13
	PA31-350	1	01ILS	16	1.2	207	20	20
		2	19ILS	196	1.2	207	20	20
		3	14VOR	135	3.2	587	20	20
Cairns	737	1	15ILS	149	1.2	311	30	23
		2	33LLZ	329	3.1	575	30	23
	PA31-350	1	15ILS	150	1.2	311	20	20
		2	33LLZ	330	3.1	575	20	20

Table 5: Continued

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Rockhampton	737	1	15GNSS	148	2.6	476	30	23
		2	33VOR	328	2.6	486	30	23
		3	Circle to 04	43	4	1046	24	13
		3	Circle to 22	223	4	1046	24	13
	PA31-350	1	15GNSS	148	2.6	476	20	20
		2	33VOR	328	2.6	486	20	20
		3	Circle to 04/22	43	2.4	706	20	20
		3	Circle to 04/22	223	2.4	706	20	20
Townsville	737	1	01ILS	17	1.5	252	30	23
		2	19VOR	197	3.4	602	30	23
	PA31-350	1	01ILS	16	1.5	252	20	20
		2	19VOR	197	3.4	602	20	20
		3	07GNSS	67	5	922	20	20
Launceston	737	1	32ILS	313	0.8	202	30	23
		2	14VOR	133	4.8	888	30	23
	PA31-350	1	32ILS	313	1.2	202	20	20
		2	14VOR	133	4.8	888	20	20
Melbourne	737	1	27ILS	263	0.8	203	30	23
		2	16ILS	160	0.8	208	30	23
		3	34GNSS	340	2.4	430	30	23
		4	09VOR	83	3.1	555	30	23
	PA31-350	1	27ILS	263	1.2	203	20	20
		2	16ILS	160	1.2	208	20	20
		3	34GNSS	340	2.4	430	20	20
		4	09VOR	83	3.1	555	20	20

Table 5: Continued

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Adelaide	737	1	23ILS	222	1.2	250	30	23
		2	05VOR	42	2.2	400	30	23
		3	12VOR	115	2.4	450	30	23
		4	30VOR	295	3.2	580	30	23
	PA31-350	1	23ILS	222	1.2	250	20	20
		2	05VOR	42	2.2	400	20	20
		3	12VOR	115	2.4	450	20	20
		4	30VOR	295	3.2	580	20	20
Darwin	737	1	29ILS	285	0.8	209	30	23
		2	11GNSS	105	1.9	357	30	23
		3	36GNSS	356	2.9	519	24	13
	PA31-350	1	29ILS	285	1.2	209	20	20
		2	11GNSS	105	1.9	357	20	20
		3	36GNSS	356	2.9	519	20	20
Perth	737	1	24ILS	241	0.8	202	30	23
		2	21ILS	196	0.8	207	30	23
		3	03ILS	16	1.5	253	30	23
		4	06VOR	61	2.6	462	30	23
	PA31-350	1	24ILS	241	1.2	202	20	20
		2	21ILS	196	1.2	207	20	20
		3	03ILS	16	1.5	253	20	20
		4	06VOR	61	2.6	462	20	20

Table 5: Continued

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Canberra	737	1	35ILS	348	0.8	230	30	23
		2	17VOR	168	5	1476	30	23
	PA31-350	1	35ILS	348	1.2	330	20	20
		2	17VOR	168	5	1476	20	20
		3	30GNSS	298	5	892	20	20
Coffs Harbour	737	1	03VOR	29	4.2	732	30	23
		2	21GNSS	209	3.8	662	30	23
	PA31-350	1	03VOR	29	4.2	732	20	20
		2	21GNSS	209	3.8	662	20	20
Sydney	737	1	16R ILS	155	0.8	212	30	23
		2	34L ILS	335	1.5	256	30	23
		3	25 ILS	242	1.5	270	30	23
		4	07 ILS	62	1.5	274	30	23
	PA31-350	1	16R ILS	155	1.2	212	20	20
		2	34L ILS	335	1.5	256	20	20
		3	25 ILS	242	1.5	270	20	20
		4	07 ILS	62	1.5	274	20	20

Alternate minima

The population of events that had been defined as ‘below landing minima’ was then assessed against the corresponding forecasts with a 2-hour or a 4-hour time offset, using the same methodology as for the landing minima assessment. If the time-offset forecast was not below alternate weather minima for the corresponding instrument approach, then this was considered to be a ‘potentially unsafe event’.

Table 6: Minimum destination weather conditions acceptable at the time of flight planning for which the carriage of fuel to an alternate would not be required

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Alice Springs	737	1	12ILS	115	4.5	850	30	23
		2	30 GNSS	295	6	1611	30	23
	PA31-350	1	12ILS	115	4.4	1081	20	20
		2	30 GNSS	295	4.4	1081	20	20
Brisbane	737	1	01ILS	16	1.2	400	30	23
		2	14VOR	16	4.4	1087	30	23
	PA31-350	1	01ILS	16	4.4	1087	20	20
		2	14VOR	16	4.4	1087	20	20
Cairns	737	1	15ILS	149	4.4	1090	30	23
		2	33LLZ	329	4.4	1090	30	23
	PA31-350	1	15ILS	149	4.4	1090	20	20
		2	33LLZ	329	4.4	1090	20	20
Rockhampton	737	1	ALL	43	6	1546	24	13
		1	ALL	223	6	1546	24	13
		1	ALL	148	6	1546	30	23
		1	ALL	328	6	1546	30	23
	PA31-350	1	ALL	43	4.4	1206	20	20
		1	ALL	223	4.4	1206	20	20
		1	ALL	148	4.4	1206	20	20
		1	ALL	328	4.4	1206	20	20
Townsville	737	1	01ILS	17	5	1000	30	23
		2	19VOR	197	4.5	950	30	23
	PA31-350	1	01ILS	17	4.4	1572	20	20
		2	19VOR	197	4.4	1572	20	20

Table 6: Continued

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Launceston	737	1	ALL	133	5	1300	30	23
		1	ALL	313	5	1300	30	23
	PA31-350	1	ALL	133	4.4	1388	20	20
		1	ALL	313	4.4	1388	20	20
		1	ALL	2	4.4	1388	20	20
		1	ALL	182	4.4	1388	20	20
Melbourne	737	1	ALL	83	3	700	30	23
		1	ALL	263	3	700	30	23
		1	ALL	160	3	700	30	23
		1	ALL	340	3	700	30	23
	PA31-350	1	ALL	83	4.4	1206	20	20
		1	ALL	263	4.4	1206	20	20
		1	ALL	160	4.4	1206	20	20
		1	ALL	340	4.4	1206	20	20
Adelaide	737	1	ALL	42	4	850	30	23
		1	ALL	222	4	850	30	23
		1	ALL	115	4	850	30	23
		1	ALL	295	4	850	30	23
	PA31-350	1	ALL	42	4	1250	20	20
		1	ALL	222	4	1250	20	20
		1	ALL	115	4	1250	20	20
		1	ALL	295	4	1250	20	20

Table 6: Continued

Location	Aircraft	Prefer-ence	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Darwin	737	1	29	285	4	850	30	23
		1	11	105	4	850	30	23
		2	36GNSS	356	6	1147	24	13
	PA31-350	1	ALL	105	4.4	1087	20	20
		1	ALL	285	4.4	1087	20	20
		1	ALL	176	4.4	1087	20	20
		1	ALL	356	4.4	1087	20	20
Perth	737	1	21	196	2	400	30	23
		1	24	241	2	400	30	23
		1	3	16	2	400	30	23
		2	06VOR	61	6	1873	30	23
	PA31-350	1	ALL	16	4.4	1193	20	20
		1	ALL	196	4.4	1193	20	20
		1	ALL	61	4.4	1193	20	20
		1	ALL	241	4.4	1193	20	20
Canberra	737	1	35ILS	348	6	2184	30	23
		2	17VOR	168	7	2244	30	23
	PA31-350	1	35	348	4.4	1964	20	20
		1	30	298	4.4	1964	20	20
		2	17VOR	168	7	2244	20	20
Coffs Harbour	737	1	ALL	29	6	1312	30	23
		1	ALL	209	6	1312	30	23
	PA31-350	1	ALL	29	4.4	1272	20	20
		1	ALL	209	4.4	1272	20	20
		1	ALL	95	4.4	1272	20	20
		1	ALL	275	4.4	1272	20	20

Table 6: Continued

Location	Aircraft	Preference	Title	Hdg (deg)	Vis (Km)	Cloud Height (ft)	Xwind Dry (Kt)	Xwind Wet (Kt)
Sydney	737	1	ALL	62	2	400	30	23
		1	ALL	242	2	400	30	23
		1	ALL	155	2	400	30	23
		1	ALL	335	2	400	30	23
	PA31-350	1	ALL	62	4.4	1189	20	20
		1	ALL	242	4.4	1189	20	20
		1	ALL	155	4.4	1189	20	20
		1	ALL	335	4.4	1189	20	20

199802815 SA227-AC Metroliner

When the aircraft arrived in the Broken Hill circuit area, the pilot observed the airfield covered in fog. After failing to become visual during an instrument approach, he decided to divert to Wilcannia. The pilot declared an emergency during the diversion, as he expected to arrive at Wilcannia with less than minimum fuel. The aircraft landed at Wilcannia with about 25 minutes of fuel remaining.

Investigation showed that the Terminal Area Forecast (TAF) requested by the pilot prior to the flight did not include a forecast of fog or any other significant weather at Broken Hill. At the time of issue of the forecast (1850 Z), the conditions at Broken Hill were considered to be too dry for fog to develop. Satellite images did not show any fog on the ground. At 2125Z, after receiving advice of increased moisture levels at Broken Hill and reports of fog at Mildura, the TAF for Broken Hill was amended to include a 30% probability of fog. The incident aircraft arrived overhead Broken Hill aerodrome at 2128 UTC and began an instrument approach.

Another company aircraft had landed at Broken Hill approximately 30 minutes earlier, and had advised the pilot of the incident aircraft that there was no fog.

ATSB Summary

Following an unforecast weather deterioration at the destination, the pilot diverted to an alternate destination, and landed with below minimum fuel reserves.

13.4 Appendix D: Operational equipment and limitations for the 'average' aircraft that were used for this analysis

PA31-350

Equipment:
VOR
ILS
DME
ADF
GNSS
2x VHF
HF
MKR BCN

Crosswind limit 20 Kt. (wet or dry runway)

Performance Category B

Boeing 737

Equipment
Dual: VOR
ILS
DME
ADF
GNSS
2x VHF
HF
MKR BCN

Crosswind limit:

	Dry runway	Wet runway
30m wide runway	24 Kt	13 Kt
> 30 m wide runway	30 Kt	23 Kt

Note: A 'wet' runway is a runway with standing water greater than 3mm deep, and without a porous or grooved surface.

Performance Category C

13.5 Appendix E: Basic data used for analysis

The calculated ratios of potentially unsafe 'below landing minima' events were based on the number of below landing minima events for which a relevant TAF existed. The number of these events was generally slightly lower than the total number of below landing minima events.

All of the data except that related to landing minima were sorted by forecast time offset, use of 'composite international' rule-set, and aircraft type.

Table 7: Total numbers of observations, below landing minima events and potentially unsafe events, based on TAF data

Location	Aircraft type	Forecast time offset (hours)	Total Number of potentially not predicted by forecast	Total Number of weather reports below landing minima	Total Number of weather reports
Alice Springs	737	2	103	579	76157
		4	132	579	76157
		4 Int'l	111	579	76157
	PA31-350	2	217	804	76157
		4	244	804	76157
		4 Int'l	226	804	76157
Brisbane	737	2	272	581	92120
		4	304	581	92120
		4 Int'l	187	581	92120
	PA31-350	2	329	1069	92120
		4	382	1069	92120
		4 Int'l	339	1069	92120
Cairns	737	2	32	338	96142
		4	34	338	96142
		4 Int'l	20	338	96142
	PA31-350	2	39	366	96142
		4	41	366	96142
		4 Int'l	27	366	96142
Rockhampton	737	2	757	1382	92852
		4	805	1382	92852
		4 Int'l	771	1382	92852
	PA31-350	2	752	1374	92852
		4	799	1374	92852
		4 Int'l	764	1374	92852
Townsville	737	2	226	515	96014
		4	244	515	96014
		4 Int'l	228	515	96014
	PA31-350	2	220	519	96014
		4	239	519	96014
		4 Int'l	228	519	96014

Table 7: Continued

Location	Aircraft type	Forecast time offset (hours)	Total Number of potentially 'unsafe' events not predicted by forecast	Total Number of weather reports below landing minima	Total Number of weather reports
Launceston	737	2	370	701	95720
		4	398	701	95720
		4 Int'l	328	701	95720
	PA31-350	2	611	1089	95720
		4	671	1089	95720
		4 Int'l	563	1089	95720
Melbourne	737	2	213	711	83235
		4	287	711	83235
		4 Int'l	151	711	83235
	PA31-350	2	159	774	83235
		4	200	774	83235
		4 Int'l	166	774	83235
Adelaide	737	2	150	404	98829
		4	171	404	98829
		4 Int'l	124	404	98829
	PA31-350	2	139	446	98829
		4	164	446	98829
		4 Int'l	130	446	98829
Darwin	737	2	330	1511	104841
		4	388	1511	104841
		4 Int'l	335	1511	104841
	PA31-350	2	354	1744	104841
		4	422	1744	104841
		4 Int'l	368	1744	104841
Perth	737	2	259	613	98058
		4	316	613	98058
		4 Int'l	195	613	98058
	PA31-350	2	500	1458	98058
		4	550	1458	98058
		4 Int'l	498	1458	98058
Canberra	737	2	467	1339	97074
		4	635	1339	97074
		4 Int'l	606	1339	97074
	PA31-350	2	785	1879	97074
		4	986	1879	97074
		4 Int'l	905	1879	97074

Table 7: Continued

Location	Aircraft type	Forecast time offset (hours)	Total Number of potentially 'unsafe' events not predicted by forecast	Total Number of weather reports below landing minima	Total Number of weather reports
Coffs Harbour	737	2	190	1224	93434
		4	224	1224	93434
		4 Int'l	210	1224	93434
	PA31-350	2	405	1722	93434
		4	449	1722	93434
		4 Int'l	431	1722	93434
Sydney	737	2	328	594	102535
		4	353	594	102535
		4 Int'l	219	594	102535
	PA31-350	2	260	625	102535
		4	278	625	102535
		4 Int'l	230	625	102535
Total	737	2	3697	10492	1227011
		4	4291	10492	1227011
		4 Int'l	3485	10492	1227011
	PA31-350	2	4770	13869	1227011
		4	5425	13869	1227011
		4 Int'l	4875	13869	1227011

199802397 SA 227- DC Metroliner

The pilot reported that he had obtained an Alice Springs Terminal Area Forecast (TAF) 1 hour before departure for The Granites at 1230 CST. The existing TAF was forecasting 7 octas of altostratus at 12,000 ft, and a separate forecast for the return flight was not obtained. The pilot said he departed The Granites at 1424 and at about 100 NM from Alice Springs he obtained the weather via the automatic terminal information service (ATIS). There had been a significant deterioration in the weather and a "SPECI" weather report had been issued. This SPECI had been issued at 1430, 6 minutes after his departure from The Granites and indicated a visibility of 10 km and 6 octas of stratus at 600 ft. These conditions meant that he was required to plan an alternate destination for the flight. The pilot conducted an instrument approach for his arrival at Alice Spring and the flight was completed with less than the company fixed reserve fuel (30 minutes) on board. The pilot was concerned that he was not passed this important operational information by ATC or Flight Service. The Manual of Air Traffic Services (MATS) indicates that the information should have been passed to the pilot.

ATSB Summary

The pilot did not receive an updated destination weather forecast of a weather deterioration, and landed in weather above the landing minima, but with below minimum fuel reserves.

Table 8: Total number of ‘below landing-minima’ events for which a TTF existed with a two-hour time offset, and the number of those events defined as unsafe by that TTF, and by the TAF in force at the same time

Location	Forecast type (2 hour time offset)	Total number of 'unsafe' events not predicted by forecast	Total number of observations below landing minima
Brisbane	TAF 737	140	292
	TTF 737	72	292
	PA31-350 TAF	148	432
	PA31-350 TTF	126	432
Cairns	TAF 737	9	121
	TTF 737	15	121
	PA31-350 TAF	16	129
	PA31-350 TTF	22	129
Rockhampton	TAF 737	24	117
	TTF 737	41	117
	PA31-350 TAF	24	117
	PA31-350 TTF	41	117
Townsville	TAF 737	4	95
	TTF 737	12	95
	PA31-350 TAF	3	93
	PA31-350 TTF	13	93
Melbourne	TAF 737	195	593
	TTF 737	101	593
	PA31-350 TAF	142	643
	PA31-350 TTF	104	643
Adelaide	TAF 737	65	196
	TTF 737	61	196
	PA31-350 TAF	61	222
	PA31-350 TTF	68	222
Darwin	TAF 737	171	857
	TTF 737	230	857
	PA31-350 TAF	178	995
	PA31-350 TTF	260	995
Perth	TAF 737	59	111
	TTF 737	18	111
	PA31-350 TAF	64	248
	PA31-350 TTF	59	248
Canberra	TAF 737	15	80
	TTF 737	52	80
	PA31-350 TAF	50	138
	PA31-350 TTF	84	138
Sydney	TAF 737	89	173
	TTF 737	62	173
	PA31-350 TAF	72	185
	PA31-350 TTF	65	185
Total	TAF 737	771	2635
	TTF 737	664	2635
	PA31-350 TAF	758	3202
	PA31-350 TTF	842	3202

Table 9: Total number of limiting phenomena that made events 'below landing minima', sorted by aircraft type and airport

Location	Cloud	Thunderstorm	Visibility	X/Wind
Alice Springs 737	64	498	43	13
Alice Springs PA31-350	64	498	95	252
Brisbane 737	52	423	118	30
Brisbane PA31-350	52	423	186	471
Cairns 737	3	206	141	4
Cairns PA31-350	3	206	141	35
Rockhampton 737	194	473	950	0
Rockhampton PA31-350	194	473	938	0
Townsville 737	14	192	274	78
Townsville PA31-350	14	192	274	25
Launceston 737	392	99	593	11
Launceston PA31-350	392	99	771	295
Melbourne 737	433	176	275	0
Melbourne PA31-350	433	176	396	0
Adelaide 737	122	177	196	0
Adelaide PA31-350	122	177	196	0
Darwin 737	16	1505	177	3
Darwin PA31-350	16	1505	438	110
Perth 737	178	281	211	36
Perth PA31-350	178	281	307	822
Canberra 737	409	402	621	86
Canberra PA31-350	545	402	857	328
Coffs Harbour 737	122	513	1287	24
Coffs Harbour PA31-350	122	513	1287	705
Sydney 737	89	435	110	0
Sydney PA31-350	89	435	155	0
Total	4312	10762	11037	3328

Note: The visibility data is normalised with data from Table 10 for use in Figure 2. Some below-minima events had more than one limiting phenomenon, so the total is greater than the total number of below-minima events.

199803515 AVRO 146-RJ70A

The crew was operating a regular public transport flight, at night, from Sydney to Norfolk Island. The operator reported that during an instrument approach procedure in conditions of poor visibility, the aircraft descended on the final approach below minimum descent altitude prior to satisfying all appropriate descent criteria. The aircraft landed safely.

ATSB Summary

The aircraft landed in weather below the minimum landing weather conditions following an unforecast weather at the destination.

Table 10: Fraction of weather reports for each airport that did not include a visibility observation

Location	Total weather reports	Total weather reports without a visibility observation	Fraction of weather reports with a visibility observation
Cairns	96142	90008	0.936
Townsville	96015	67557	0.704
Perth	98065	44070	0.449
Rockhampton	92858	50024	0.539
Alice Springs	76157	8083	0.106
Sydney	102535	62115	0.606
Brisbane	92120	62375	0.677
Launceston	95726	50132	0.524
Melbourne	83235	54933	0.660
Adelaide	98830	59354	0.601
Coffs Harbour	93435	52373	0.561
Darwin	104841	64799	0.618
Canberra	97078	49338	0.508
Total	1227037	715161	0.576

199904029 A320-211

The aircraft departed with sufficient fuel to reach its destination, but not to continue to an alternate, as there was no requirement to carry extra fuel, based on the weather forecast.

When the aircraft arrived at its destination, fog was spreading across the airfield. The flight crew conducted two instrument approaches at their destination, but were not able to land because of the fog. They then conducted a category three autoland instrument approach at the destination and landed without incident. The destination was not equipped or certified for a category three instrument landing.

ATSB Summary

Following an unforecast weather deterioration at the destination, the flight crew conducted a category three autoland in weather below the landing minima.

199802677 PA-31-350

After studying weather forecasts for King Island, Wynyard and Launceston, the pilot planned the flight with enough fuel to fly to Wynyard, conduct a GPS arrival plus a VOR approach if necessary, and then for a diversion to Launceston if necessary. At the time of planning there was no holding requirement on Launceston.

The pilot conducted the Wynyard GPS arrival, but did not become visual at the minima; he then conducted the VOR approach, but again did not become visual, so he diverted to Launceston. Launceston ATIS advised that an ILS was required. Unexpectedly having to fly the ILS added more flight time than originally planned. On completion of the ILS and landing, the fuel on board the aircraft was 50 litres, which was 25 litres out of the planned fixed reserve. While flying the ILS the pilot also discovered that the weather at Launceston was worse than forecast or advised by flight service. He subsequently submitted an incident report complaining about the inaccuracy of the weather forecasts.

ATSB Summary

The pilot diverted to an alternate aerodrome following an unforecast weather deterioration at the destination, and subsequently landed with below minimum fuel reserves.

Table 11: Table of below landing minima events sorted by the phenomena that created the below-minima event

Location	Aircraft Name	Cloud only	TS only	Vis only	Xwind only	TS Vis	TS Cloud	TS Vis Cloud	Vis Cloud	Xwind Cloud	TS Xwind	TS Vis Xwind	TS Xwind Cloud	TS Vis Xwind Cloud	Xwind Vis	Vis Xwind Cloud	Grand Total
Alice Springs	737	43	479	12	7	11	1	1	19	0	6	0	0	0	0	0	**579**
Alice Springs	PA31-350	40	423	53	195	17	1	0	22	0	54	2	0	1	0	0	**808**
Brisbane	737	21	412	76	30	11	0	0	31	0	0	0	0	0	0	0	**581**
Brisbane	PA31-350	13	397	125	466	21	0	0	39	0	4	1	0	0	0	0	**1066**
Cairns	737	3	192	125	2	14	0	0	0	0	0	0	0	0	2	0	**338**
Cairns	PA31-350	3	192	121	28	13	0	0	0	0	0	1	0	0	6	0	**364**
Rockhampton	737	47	410	741	0	62	0	1	146	0	0	0	0	0	0	0	**1407**
Rockhampton	PA31-350	48	413	733	0	59	0	1	145	0	0	0	0	0	0	0	**1399**
Townsville	737	0	173	242	72	15	0	0	14	0	3	1	0	0	2	0	**522**
Townsville	PA31-350	0	171	244	20	16	0	0	14	0	5	0	0	0	0	0	**470**
Launceston	737	175	97	376	11	1	1	0	216	0	0	0	0	0	0	0	**877**
Launceston	PA31-350	144	93	520	293	3	0	1	247	0	2	0	0	0	0	0	**1303**
Melbourne	737	260	176	102	0	0	0	0	173	0	0	0	0	0	0	0	**711**
Melbourne	PA31-350	204	173	164	0	3	0	0	229	0	0	0	0	0	0	0	**773**
Adelaide	737	60	177	134	0	0	0	0	62	0	0	0	0	0	0	0	**433**
Adelaide	PA31-350	60	177	134	0	0	0	0	62	0	0	0	0	0	0	0	**433**
Darwin	737	14	1464	134	3	41	0	0	2	0	0	0	0	0	0	0	**1658**
Darwin	PA31-350	10	1365	307	67	110	0	0	6	0	28	2	0	0	13	0	**1908**
Perth	737	91	276	121	32	2	0	0	87	0	3	0	0	0	1	0	**613**
Perth	PA31-350	66	266	187	809	5	0	0	112	0	10	0	0	0	3	0	**1458**
Canberra	737	274	393	481	80	3	0	0	135	0	4	2	0	0	0	0	**1372**
Canberra	PA31-350	350	379	656	311	6	0	0	195	0	17	0	0	0	0	0	**1914**
Coffs Harbour	737	50	432	1128	15	79	0	1	71	0	1	0	0	0	8	0	**1785**
Coffs Harbour	PA31-350	45	430	1070	623	77	0	0	66	5	3	2	0	1	66	5	**2393**
Sydney	737	61	434	81	0	1	0	0	28	0	0	0	0	0	0	0	**605**
Sydney	PA31-350	47	433	111	0	2	0	0	42	0	0	0	0	0	0	0	**635**
Grand Total		**2129**	**10027**	**8178**	**3064**	**572**	**3**	**5**	**2163**	**5**	**140**	**11**	**0**	**2**	**101**	**5**	**26405**

Note: Some events had more than one limiting phenomenon, so the total will be lower than for the total number of events.