Technical Report 1

Astral Aviation Consultants – Review of Runway Length
FINAL REPORT

WELLINGTON INTERNATIONAL AIRPORT

REVIEW OF PROPOSED RUNWAY EXTENSION LENGTHS

ASTRAL LIMITED

April 2016
## CONTENTS

1  Summary ................................................................................................................. 5

1.1  Findings .................................................................................................................. 5

1.2  Recommendations ................................................................................................. 8

2  Reference reports and data ...................................................................................... 9

3  Assumptions .............................................................................................................. 9

4  Existing runway and study extensions .................................................................... 10

4.1  Operational data .................................................................................................... 10

4.2  Clearway .................................................................................................................. 10

4.3  Runway 34 obstacle clearance ................................................................................. 10

4.4  Runway slope .......................................................................................................... 11

4.5  Ambient conditions ............................................................................................... 11

4.6  Line up allowance .................................................................................................. 12

4.7  Proposed extension ............................................................................................... 12

5  Candidate aircraft ................................................................................................... 14

5.1  Types considered .................................................................................................. 14

5.2  Minimum control speed considerations ................................................................ 14

5.3  Astral comments on aircraft data ......................................................................... 17

6  Assessment of performance ..................................................................................... 18

6.1  Method .................................................................................................................... 18

6.2  Results ..................................................................................................................... 18

6.3  Comments .............................................................................................................. 18

6.3.1  Runway 34 flight path obstacles ....................................................................... 18

6.3.2  Wet runway takeoff ......................................................................................... 19

6.3.3  Landing performance ....................................................................................... 21
6.3.4 Individual aircraft performance capability ........................................21
6.3.5 Viable routes ....................................................................................22
6.3.6 Economic impact of payload restrictions .........................................23
6.3.7 Conservatisms in the study ...............................................................24

Tables

Table 1 Runway data 13
Table 2 Candidate aircraft and order numbers 15
Table 3 Candidate aircraft data 16
Table 4 Analysis results pass/fail summary-full passenger load 20

Figures

Figure 1 777-200ER takeoff weights required and available 25
Figure 2 787-8 (B64) takeoff weights required and available 27
Figure 3 787-8 (B70) takeoff weights required and available 29
Figure 4 787-9 (B74) indicative takeoff weights required and available 31
Figure 5 A350-800NEO takeoff weights required and available 33
Figure 5a A350-900NEO takeoff weights required and available 35
Figure 6 A350-900 takeoff weights required and available 37
Figure 7 A350-1000 indicative takeoff weights required and available 39
Figure 8 A330-200 takeoff weights required and available 41
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 9</td>
<td>A320-200 takeoff weights required and available</td>
<td>43</td>
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<tr>
<td>Figure 10</td>
<td>A320NEO takeoff weights required and available</td>
<td>45</td>
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<tr>
<td>Figure 11</td>
<td>A321NEO takeoff weights required and available</td>
<td>47</td>
</tr>
<tr>
<td>Figure 12</td>
<td>777-200ER and 787-8 landing weights required and available</td>
<td>49</td>
</tr>
<tr>
<td>Figure 13</td>
<td>787-9 landing weights required and available</td>
<td>50</td>
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<tr>
<td>Figure 14</td>
<td>A350-900 and A350-1000 landing weights required and available</td>
<td>51</td>
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<td>Figure 15</td>
<td>A330-200 landing weights required and available</td>
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<td>Figure 15a</td>
<td>A330-800NEO and A330-900NEO landing weights required and available</td>
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<tr>
<td>Figure 16</td>
<td>A320-200 A320EO landing weights required and available</td>
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<tr>
<td>Figure 17</td>
<td>A321NEO landing weights required and available</td>
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1 Summary

1.1 Findings

This is an update of an earlier report (November 2013) that reviewed, for Wellington International Airport Limited (WIAL), a number of runway extension length options to determine which would allow viable operations of long haul flights from Wellington to east Asian and western North American destinations. That earlier work looked at four incremental runway extension options from a 100m extension to a 400m extension, and determined that long haul operations become increasingly more viable with runway extensions over 300m.¹

Based on preliminary investigative work undertaken by others (that this author was not involved with producing) WIAL adopted a 355m southern extension option, delivering a takeoff run available (TORA) of at least 2300m. This updated report is therefore specific to a 355m southward extension, adds discussion regarding the feasibility and benefit of the extension for narrow body international jet operations operating Trans-Tasman and south west Pacific routes. The update also includes new data on a number of aircraft (787-9, A350, A330-800/900NEO, A320NEO and A321NEO)

The report is based on extensive information on aircraft performance provided by Airbus, Jeppesen (for Boeing) (the OEMs) and Lean Engineering, a US based aviation consultancy.

At WIAL’s request Astral’s study focuses on 8 wide body aircraft types (777-200ER, 787-8 (two versions), 787-9, A330-200 and -800/-900NEO, A350-900 and -1000) over four routes (WLG to SIN, CAN, PEK and LAX). The 787, A350 and A330NEO variants will form the bulk of the world’s long haul fleet over the next few decades. Three narrow body aircraft (A320, A320NEO and A321NEO) are included operating over four

¹ A “runway extension” in this report mean an increase in the runway length available for take-off and landing. The length of the associated reclamation will be more.
Tasman/Regional routes. No analysis was possible for the new 737-800Max as no information was received from Boeing on the projected performance of the aircraft.

Astral’s review assesses the OEMs data, in particular their aircraft operating weight empty (OEW) estimates, and estimates of required takeoff and landing weights at WLG for a full passenger load and maximum payload over each of the study routes. The required takeoff and landing weights are then compared to the OEM’s estimated takeoff weights for the existing runway and the proposed 355m runway extension to the south.

Astral’s summary findings are:

- The proposed 355m extension enables four of the nine candidate wide body aircraft to operate long-haul routes from Wellington Airport (WLG) to most east Asian destinations (including Bangkok, Bali, Guangzhou, Jakarta, Hong Kong, Manila, Shanghai, Singapore, Kuala Lumpur, Tokyo, Osaka and Seoul) with a full passenger load under the study takeoff ambient conditions of 21°C, wet or dry runway with 5 knots of headwind.2

- The US West Coast can also be reached by four candidate aircraft, and Beijing (PEK) could be reached by the A350-900, under more favourable dry takeoff runway conditions.

- A lesser extension would not provide this capability in particular due to minimum control speed considerations on takeoff and wet runway landing restrictions.

- The 787-8 and -9 performance is below previous (2013) indications largely due to the aircrafts' in service OEW being much higher than earlier Boeing estimates. The B64 engined version (the most prevalent) in particular has very limited capability to operate to the target destinations.

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2 The A350-1000 and 777-200ER require dry takeoff runway conditions
There is the option on the 787-8 of airlines up rating to B70 engine thrust which would allow the aircraft to operate to all the study destinations except PEK with a full (228 seat) passenger load.\textsuperscript{3}

The runway extension is particularly beneficial for wide body aircraft landing, the existing runway being very short for such aircraft especially under wet runway conditions.

The narrow body aircraft, especially the A320 and A321NEO, also benefit from a runway extension for operations to four longer range Trans-Tasman and Regional Pacific destinations. For the A320 operations to these destinations is not viable without the runway extension. The benefit for the 737-800 would be similar.

Obtaining a takeoff flight path on runway 34 that enables the Newlands Ridge flight path obstacles to be avoided is essential to obtaining the full benefit from the runway extension. The study assumes a “required navigation performance” (RNP) path is available and is based on the indicative takeoff flight path obstacle clearance requirements for this.\textsuperscript{4} However it should be noted that this flight path is not yet defined for wide body aircraft use.\textsuperscript{5}

While it is clearly desirable for an aircraft to be able to carry its maximum payload over a particular route, operating economics may still be attractive to an airline if this is not possible. Generally, due to their higher passenger yields, full service carriers (FSC) are more able to accept payload shortfalls than low cost carriers (LCC). Providing a full passenger load can be carried and the demand and yield are favourable, operations should be economically viable for a FSC.

\textsuperscript{3} Usually there is a one-off charge per aircraft for the Flight Manual change, and an increase in maintenance costs due to the engine being operated at a higher thrust rating. The maintenance cost increase can be minimised by only using the additional thrust when payload “on the day” requires it.

\textsuperscript{4} RNP is a very accurate satellite based navigation system used in modern jet transport aircraft.

\textsuperscript{5} Currently a wide body aircraft operator is evaluating the RNP flight path and indications are that a suitable path can be developed.
• This study is based on a set of criteria which are generally conservative. It is expected in-service payloads would tend to be higher than the estimates in this report.

1.2 Recommendations

Astral recommends the 355m runway extension as being the minimum viable for long-haul operations of wide body aircraft at Wellington Airport. However even with the extension the runway is comparatively short for these types of aircraft and runway grooving is seen as essential to maintain good braking performance under wet runway conditions.

The RNP takeoff path to the north, avoiding the Newlands Ridge, is required to achieve the best possible take-off weights on runway 34 but has not yet been validated. It is recommended this work be reviewed in conjunction with Airways Corporation (Group EAD Asia Pacific) to fully design and validate a suitable path.
2 Reference reports and data

The following reports and data provided by WIAL and Airbus were referred to in preparing Astral’s study:

- Jeppesen takeoff and landing performance data for the 777-200ER and 787-8
- Jeppesen payload-range data for the 777-200ER and 787-8
- Airbus 2013-5 De-Laforcade A350 and A330 Performance Analysis WIAL RE1110929_v3
- Takeoff weights data using optimum V1 provided by Jeppesen for the Boeing aircraft (except the 787-9)
- Runway 34 RNAV(RNP) engine out standard instrument departure path (EOSID) and obstacle data
- Lean Engineering Limiting Takeoff weight and OEW Information for the 787-8 and -9 at Wellington International Airport
- Updated A350-900 and -1000 takeoff, landing and payload range data provided by Airbus
- A330-800/900NEO, A330-200, A330-200NEO, A320, A320NEO and A321NEO takeoff, landing and payload range data provided by Airbus

3 Assumptions

Assumptions made in the review are described in the various sections of the report. In particular reliance has been placed on:

- The OEM’s and Lean Engineering’s calculation of runway limited takeoff weight for the runway configuration, flight path obstacles and ambient conditions.
- The availability of 355m clearway on runway 16 takeoff (see section 4.2).
- The availability of an RNP based engine inoperative departure procedure that avoids climbing over the Newlands Ridge (see section 4.3)
Where available takeoff weights using optimum V1 speed have been used for the Boeing 777-200ER, 787-8, -9 aircraft.

4 Existing runway and study extensions

4.1 Operational data

The operational data for the existing runway and the runway with the proposed extension are listed in table 1. The following comments apply.

4.2 Clearway

The existing runway has declared takeoff distance available (TODA) which reflects a 355m clearway in the 16 direction and 379m in the 34 direction. IWIAL has confirmed that the 355m clearway will still be available in the 16 direction after the runway extension.

It is essential that an adequate clearway is provided off each end of the extended runway as this compensates to some extent for runway length.6

4.3 Runway 34 obstacle clearance

The takeoff flight path obstacle in the 34 direction specified by WIAL in its data request to Airbus and Jeppesen is the transmission pylon on the Newlands Ridge, as specified in the aerodrome Type A obstruction chart. WIAL has commented that this obstacle, which significantly limits takeoff weights in the 34 direction, could be avoided by aircraft using an alternative flight path with lesser obstructions in the event of a takeoff engine failure.

It is understood AirNZ A320 aircraft currently use the runway 34 RNAV (RNP) EOSID as provided to Astral by WIAL. The obstacle listing provided with this procedure indicates the terrain which would limit takeoff weight is largely avoided. However an airspace danger area (D627), with an upper limit of 1000ft, set aside for model aircraft flying lies within the path requiring discussion with the CAA if there is a conflict with aircraft using

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6 Depending on the nature of the aircraft performance limitation on the runway each 1m of clearway has the effect of about 0.5m runway extension up to a maximum of around 300m.
the RNP procedure. WIAL is confident any conflict can be resolved and Astral concurs with this. The EOSID is currently restricted to approach category C aircraft which includes the 777-200ER, 787-8 and A330-200/300 but not the 777-300ER, 787-9 or A350. The latter aircraft are approach category D by virtue of their faster speed in the approach and departure phase. Astral considers that, if necessary, the procedure could be adapted to accommodate the faster aircraft. In addition the following should be noted:

- The EOSID is only available to operators approved by CAANZ and their own regulators. Depending on the level of an airlines existing use of RNP specific pilot training and operational approvals may be required.
- Airlines not familiar with EOSID operations should be appraised of the benefits of this procedure for improving runway 34 takeoff weights in discussions with WIAL.
- RNP procedures are becoming well established world wide and in the timeframe of the runway extension the effort required for pilot training and gaining regulatory approval may not be an issue.

4.4 Runway slope

Under CAANZ aerodrome design standards runway slope is defined as the difference in elevation between the runway ends divided by the runway length. Currently the north runway end is about 5.3m higher than the south end and the profile shows the low point to be approximately in the middle with both ends having an upslope.

The runway design for the extended runway continues the up-slope from the elevation low point in the mid section of the runway. This effectively halves the runway up-slope in the 34 takeoff direction, providing a useful takeoff performance gain.

4.5 Ambient conditions

Ambient conditions for takeoff are assumed to be 21°C with 5 knots headwind with standard air pressure (1013hPa). This equates to a typical summers day. Headwind of

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7 It is expected that the approach speed category of the A330-800/900NEO will also be C
5kts was assumed on the basis of data supplied by WIAL showing the mean headwind on the runway exceeds 5kts 85% of the time during non-curfew hours.

It is common in route analysis to calculate payloads by season, typically summer and winter to account for both variations in takeoff performance with ambient temperature and variations in enroute winds with season. However for the Asian routes in particular there is only a small variation in seasonal enroute winds so consequently use of summer takeoff conditions is conservative.

Ambient conditions for landing are 1013hPa air pressure and nil headwind. Air temperature has little effect on landing performance.

The analysis has been done with the runway both wet and dry for takeoff and landing. The existing runway is grooved and it is strongly recommended any extension is also grooved as this significantly enhances runway safety in wet conditions and reduces the number of occasions wet runway penalties need to be applied by flight crew.\(^8\)

Short runways, especially when wet, can be extremely limiting for large aircraft due to minimum control speed requirements. This is discussed in section 5.2.

### 4.6 Line up allowance

The OEMs have included a 90 degree line-up allowance (LUA) for the aircraft to line up on the runway at the start of takeoff, although Airbus does not appear to have stated the actual metres adjustment. LUA is not yet mandatory for New Zealand airlines, but is for Australian airlines. Taxiway entry should be designed to minimise the amount of lineup allowance required.

### 4.7 Proposed extension

As defined in Table 1, the proposed extension to the runway is 355m to the south. The existing 355m south clearway will also be available at the end of the extended strip. Extension to the south has the advantage of not steepening the effective gradient required to clear flight path obstructions in the 34 takeoff direction.

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\(^8\) Some airlines allow pilots discretion in applying wet runway performance adjustments when the runway is grooved, depending on the intensity of rain falling at the time.
Review of runway extension length

Table 1: Runway data

<table>
<thead>
<tr>
<th></th>
<th>16 Existing</th>
<th>34 Existing</th>
<th>16 Extended</th>
<th>34 Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>TORA m</td>
<td>1945*</td>
<td>1921*</td>
<td>2300</td>
<td>2300</td>
</tr>
<tr>
<td>ASDA m</td>
<td>1945*</td>
<td>1921*</td>
<td>2300</td>
<td>2300</td>
</tr>
<tr>
<td>TODA m</td>
<td>2300*</td>
<td>2300*</td>
<td>2655</td>
<td>2655</td>
</tr>
<tr>
<td>LDA</td>
<td>1815*</td>
<td>1815*</td>
<td>2170</td>
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<td>SLOPE</td>
<td>0.29%D*</td>
<td>0.29%U*</td>
<td>0.15%D</td>
<td>0.15%U</td>
</tr>
<tr>
<td>OBS</td>
<td>nil</td>
<td>Note 1</td>
<td>nil</td>
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</tr>
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</table>

Denotes data taken from current AIP Aerodrome Operational Data page NZWN AD 2- 52.1 effective 26 Jul 12
TORA = takeoff run available
ASDA = accelerate-stop distance available
TODA = takeoff distance available.
LDA = landing distance available
SLOPE = runway declared slope (D = downslope, U = upslope)
OBS = takeoff flight path obstacles

Note 1: Obstacles based on AirNZ RNP flight path reviewed by Astral. Most critical obstacles are:
1104ft at 17903m / 18282m (height in ft above lift off end of clearway, distance in m from start of takeoff roll)
1463ft at 28583m / 28962m (lesser distance for existing runway)
1556ft at 30529m / 30908m
1677ft at 35900m / 36279m
5 Candidate aircraft

5.1 Types considered

The candidate wide body aircraft as specified by WIAL are listed in Table 2 together with current order numbers as researched by WIAL. These candidate aircraft cover the bulk of wide body aircraft orders over the next few years, with the 787, A350 and A330NEO becoming the most predominant long haul aircraft in airlines fleet in the coming years.

Table 3 includes basic data on the wide and narrow body aircraft as provided by the OEMs, WIAL (in relation to seat counts) or as reviewed by Astral (in relation to OEW).

5.2 Minimum control speed considerations

When, following an engine failure at the critical speed (V1) on takeoff, the pilot elects to continue the takeoff the aircraft speed must be adequate to allow the rudder to provide enough directional control to keep the aircraft straight.

On wet runways V1 is reduced to increase the margin for stopping should the pilot elect to do so. This can reduce the speed below that required for adequate directional control, effectively meaning the aircraft can’t takeoff unless a lower takeoff thrust rating which raises the minimum control speed is used. However the use of a lower thrust rating substantially reduces takeoff weight which may mean only short flights can be operated from the runway.

For aircraft that have not yet been certificated (i.e. new designs such as the A350-1000 or re-engined such as the Airbus NEO’s) minimum control speeds have not yet been determined meaning there is some uncertainty about the takeoff performance of those aircraft on the relatively short runway (even when extended) for those aircraft.

Airbus has provided wet runway data for the A350-1000 including its assessment of minimum control speed. This data indicates that this aircraft will be limited by minimum control speed in some circumstances on the extended runway. This presents a risk to the performance assessment as certification data may be more adverse. Airbus has also provided wet runway data on the A330-800NEO which indicates the aircraft will not be affected by minimum control speed when certificated.
The A320 and A321NEO are most unlikely to be affected as those aircraft are designed to operate off runways of around 2000m length.

The 787-8 is affected by minimum control speed on the existing runway but not on the extended. The 787-9 is not affected on either existing or extended.

Table 2: Candidate Aircraft Orders/Deliveries (Nov 2015)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Deliveries</th>
<th>Orders</th>
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<tr>
<td>777-200ER</td>
<td>422</td>
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<tr>
<td>787-8</td>
<td>280</td>
<td>450</td>
</tr>
<tr>
<td>787-9</td>
<td>60</td>
<td>528</td>
</tr>
<tr>
<td>A330-200</td>
<td>557</td>
<td>631</td>
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<tr>
<td>A350-900</td>
<td>10</td>
<td>596</td>
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Table 3: Candidate aircraft

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<th>MCTOW</th>
<th>MLW</th>
<th>MZFW</th>
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<th>Astral OEW</th>
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<td>52580</td>
<td>297560</td>
<td>213188</td>
<td>199580</td>
<td>145000</td>
<td>147700</td>
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<td>787-8</td>
<td>Genx-1B64/B70</td>
<td>228(242**)</td>
<td>43318</td>
<td>227930</td>
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<td>22100</td>
<td>97000</td>
<td>79200</td>
<td>75600</td>
<td>52800</td>
<td>53500</td>
</tr>
</tbody>
</table>

* includes tare weight of containers required for passengers’ bags.  ** Typical 3 class OEM configuration
5.3 Astral comments on aircraft data

The assumptions made by the OEM’s regarding aircraft configuration can have a significant effect on payload-range capability, in particular operating empty weight (OEW), seats installed, engine thrust rating and structural weight limits.

The OEM's data is frequently optimistic with regards to aircraft performance, especially operating empty weight (OEW). A realistic estimation of OEW is critical as every 1000kg under estimate equates to a 10 passenger reduction in payload that can be carried on longer range flights.

The following in-service aircraft have relatively well known OEW and typical in-service values have been used in the study:

- 777-200ER
- 787-8
- A330-200
- A320

The following aircraft are in service, but in relatively few numbers so although in-service weights are used the OEW for other airlines may vary from that assumed in the study:

- 787-9
- A350-9

The following aircraft are derivatives of existing aircraft and therefore have at least partially known OEM’s but variations in design may result in increased or (less likely) decreased weight.

- A350-1000
- A330-800NEO
- A330-900NEO
- A320NEO
- A321NEO
6 Assessment of performance

6.1 Method

For the wide body aircraft Astral ran route performance analysis over four sectors (SIN, CAN, PEK and LAX) of interest to WIAL to determine the required aircraft takeoff weight (TOW) for the sectors based on 85% 18enroute summer season winds (to match the summer season 21°C takeoff temperature assumption).

For the narrow body aircraft the same analysis was done for four Trans-Tasman and regional Pacific sectors (CNS, RAR, APW and ADL) nominated by WIAL.

The analysis assumes typical airline reserve fuel loads and was done using Astral’s proprietary software and aircraft performance database, calibrated against OEMs data.

TOW’s required for maximum payload and a full passenger payload (no cargo) were calculated and compared with the OEM’s calculated runway limited takeoff weights for the existing and extended runway options.

Landing performance was also assessed based on OEMs data assuming a dry and wet runway conditions.

6.2 Results

The results of the analysis are shown in Figures 1 to 17 for the aircraft types reviewed and the eight routes of interest for the existing runway and the 355m extended runway.

Table 4 gives an overall pass/fail summary for operation with full passengers only on the basis that if a full passenger load can be carried the operation should be attractive to airlines, especially full service carriers.

6.3 Comments

6.3.1 Runway 34 flight path obstacles

Clearly the ability to avoid the takeoff flight path obstacles on runway 34 is a very significant factor in determining the viability of the runway extension. Astral’s understanding is runway 34 is used 50-60% of the time and to have that great a
percentage of flights with reduced payload “on the day” due to wind direction would not be encouraging to the airlines.

Consequently Astral strongly recommends further investigation of the ability to develop a departure path on runway 34 that avoids the obstacles is further investigated as discussed in section 4.3. The would normally be done by the airlines working with the departure flight procedure designer (Airways Corporation) such as was done several years ago at Queenstown Airport.

6.3.2 Wet runway takeoff

A wet runway generally has reduced friction characteristics which increase aircraft braking distances. On takeoff this affects the emergency stopping distance required to be allowed for in determining the maximum weight and aircraft can takeoff at.

Airline and OEMs policy on wet runway operations varies. For example some policies allow credit for grooved runways being rated as “dry” even when wet due to the drainage provided by the grooves.

Data provided by WIAL suggests wet runways occur approximately 9% of occasions. This analysis includes assessment for both wet and dry runways so the effect of a wet runway takeoff on payload, which varies by aircraft type, can be seen. There is no hard and fast rule that airlines require a full passenger load to be able to be carried under both wet and dry conditions. Each airline will make its own assessment of its ability to manage payload shortfalls “on the day” and may well decide it is quite viable to operate when a wider range of factors such as the likely ambient takeoff temperature and head wind in combination with a wet runway are considered.
### Table 4: Capability from extended runway (full passenger load)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>ROUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WLG-SIN</td>
</tr>
<tr>
<td>355m extended runway</td>
<td></td>
</tr>
<tr>
<td><strong>WLG-SIN</strong></td>
<td>✔ ✔</td>
</tr>
<tr>
<td><strong>WLG-CAN</strong></td>
<td>✗</td>
</tr>
<tr>
<td><strong>WLG-PEK</strong></td>
<td>✔ ✔</td>
</tr>
<tr>
<td><strong>WLG-LAX</strong></td>
<td>✗</td>
</tr>
<tr>
<td><strong>XXX-WLG</strong></td>
<td>✔ ✔</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>ROUTE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WLG-CNS</td>
</tr>
<tr>
<td><strong>A320</strong></td>
<td>✔</td>
</tr>
<tr>
<td><strong>A320NEO</strong></td>
<td>✔ ✔</td>
</tr>
<tr>
<td><strong>A321NEO</strong></td>
<td>✔ ✔</td>
</tr>
</tbody>
</table>

- ✔ ✔ Operation possible with a full passenger payload under study conditions with dry runway
- ✔ ✔ Operation possible with a full passenger payload under study conditions with wet or dry runway
- ✗ Operation not possible with full passenger payload under study conditions on dry runway
- ✔ Runway 16 or 34 wet runway landing can be made with a full passenger load
- ✔ ✔ ✔ Runway 16 or 34 wet runway landing can be made with a full payload
6.3.3 Landing performance

On the existing runway only the 777-200ER, 787-8 and 787-9 can land with a full passenger load when the runway is wet but are unable to land with a full payload.

On the 355m extended runway none of the study aircraft have restrictions landing with a full payload apart from the A350-900 which can at least land with a full passenger load and a significant amount of cargo.

6.3.4 Individual aircraft performance capability

Wide body aircraft

None of the candidate wide body aircraft are able to operate all four study routes unrestricted, although as discussed in section 6.3.6 this does not necessarily make the services unattractive for airlines.

Of the existing wide body aircraft the 777-200ER, 787-8(B70 thrust), 787-9 and A350-900 have the greatest capability with WLG-PEK only being a realistic possibility with the A350-900 when taking off on a dry runway. The A330-200 is only able to operate WLG-SIN with a full passenger load under study conditions, and the 787-8(B64 thrust) cannot operate any of the sectors with a full passenger load.

The 787-8 with B64 thrust engines has a somewhat disappointing performance at Wellington and it should be noted that most delivered aircraft have this thrust rating rather than the better performing B70 rating (although aircraft can be uprated).

Of the future aircraft, the A330-800NEO will have excellent performance from the extended runway, better than that of the 787-8/9. Based on current OEMs data the A350-1000 will not be able to operate any of the study sectors with a full passenger load under wet runway conditions but could operate to SIN on a dry runway.

The A330-900NEO does not have particularly good performance except to SIN where a full payload could be carried on a dry runway.

No data was available from Boeing to assess the performance of the 777X models. Based on public domain data it appears likely the 777-8X (slightly larger than the existing 777-200ER) will have performance similar to that of the A350-900, and the
Review of runway extension length

larger 777-9X similar to that of the A350-1000. On that basis only the 777-8X is likely to be capable of WLG operations beyond Singapore.

The extended runway particularly assists the landing capability of the wide body aircraft. This is important as the existing runway is very short for wide body aircraft of this size.

**Narrow body aircraft**

As indicated in figures 9 to 11, the existing A320 and future A321NEO cannot viably operate the Trans-Tasman and Regional Pacific sectors nominated by WIAL from the existing runway, however the future A320NEO could with just a slight payload restriction on runway 34 when wet.

The extended runway benefits the A320 and A321NEO by enabling the aircraft to operate at or close to their maximum takeoff weights. The A320NEO also benefits but to a lesser extent as its performance from the existing runway would already be very good based on OEMs data.

The 737-800 can also be expected to benefit from the runway extension as it tends to require more runway that the A320. As no data is available from Boeing on the updated version of the 737 (the 737Max) currently under development its performance cannot be estimated with any certainty, however it is likely to be at least as good as that of the A321NEO given the competitive tension between the OEMs in this category of aircraft.

### 6.3.5 Viable routes

Astral’s analysis indicated that CAN and LAX (12-12.5 hrs flight time and 5700-5900nm still air distance) is the realistic limit ex WLG for most of the candidate aircraft with the proposed 355m extension. PEK is approximately 13.5hr flight time and may be possible with the A350-900 under favourable conditions.

However 12-12.5 hr flight time covers most east Asian cities, including Bangkok, Bali, Guangzhou, Jakarta, Hong Kong, Manila, Shanghai, Singapore, Kuala Lumpur, Tokyo, Osaka and Seoul, and West Coast USA.
6.3.6 Economic impact of payload restrictions

It is not unusual for long haul routes to be operated with payload restrictions due to aircraft performance limitations. Restrictions do not necessarily make the routes uneconomic, as route economics and therefore profit to the airlines depend entirely on demand and yield, for both passengers and freight.

For example full service airlines with high yields arising from first and business class passengers can operate with low seat counts, such as JAL’s 186 seat 787-8’s, compared to LCC’s which have very small margins and very high seat counts (Jetstar has 330 seats on its 787-8).

However as a general statement restrictions below a full passenger load (which could range from 186 to 330 seats in the above 787-8 example), are not attractive to airlines.

Examples of routes operated from New Zealand in the past with less than full payload capability include the 767 flights from Auckland to Japan, Seoul, Bangkok, Singapore and currently to Shanghai.

Freight can be a significant revenue earner to full service airlines which have established freight networks, with yields typically $2/kg. Freight can be very directional and less time sensitive enabling uplift on days when passenger loadings are down. It also has more ways it can be moved, for typically by combination of aircraft and truck to final destination.

Generally the lack of payload capacity for freight would not be a major disincentive provided passenger yields are good, and in the extended runway case the full freight potential would be realised inbound anyway.\(^9\)

For these reasons Astral’s recommendation is that a 355m extension is the minimum required to provide at least a full passenger load to the target destinations with the candidate aircraft in representative seating configurations for the airlines concerned.

\(^9\) The A350-900 may be slightly restricted in freight capacity inbound when landing on a wet runway.
6.3.7 Conservatisms in the study

The study has been undertaken using criteria typical of airline payload-range analysis that are intended to be conservative, for example the use of 85% enroute winds which by definition would only be expected to be exceeded on 15% of occasions.

On any given day payloads are likely to be higher than indicated in this report, for example due to:

- Reduction in the 5% contingency fuel assumed in the study to be carried over the entire route. Under normal circumstances this can be reduced to only the last part of the route, increasing payload by about 2000kg or 20 passengers.

- Use of a closer destination alternate. For example there are 2 suitable alternate airports within 100nm of Shanghai, compared to the study assumption of a 150nm diversion to alternate.

- Takeoff on a typical 15°C day with 10kts of wind could increase takeoff weight by about 3500kg and payload by 2500kg (or 25 passengers).

- Modern flight planning systems can select an optimum route to minimise flight time and fuel requirement by taking advantage of prevailing enroute winds. Reducing headwind component by 10kts over a 12 hr flight can reduce fuel load by 1200kg allowing a similar increase in payload (12 passengers).

As operating experience is gained on a route generally bookable payloads can be increased to remove some of the initial conservatisms.
Review of runway extension length

Figure 1: 777-200ER takeoff weights required and available

![777-200ER takeoff weight required WLG-PEK](image)

- **147700kg OEW 100kg/pax, 5% fuel cty**
- **SUMMER ENROUTE WINDS**

### 777-200ER takeoff weight required WLG-PEK

- **takeoff weight required max payload**
- **takeoff weight required max pax only**
- **takeoff weights available 21deg C 5kts head wind**

### Runway option/condition

- 15dry
- 16wet
- 34dry
- 34wet
- 15D dry
- 16D wet
- 34D dry
- 34D wet

### 777-200ER takeoff weight required WLG-CAN

- **147700kg OEW 100kg/pax, 5% fuel cty**
- **SUMMER ENROUTE WINDS**

### 777-200ER takeoff weight required WLG-CAN

- **takeoff weight required max payload**
- **takeoff weight required max pax only**
- **takeoff weights available 21deg C 5kts head wind**

### Runway option/condition

- 15dry
- 16wet
- 34dry
- 34wet
- 15D dry
- 16D wet
- 34D dry
- 34D wet
Review of runway extension length

777-200ER takeoff weight required WLG-LAX
147700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

777-200ER takeoff weight required WLG-SIN
147700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS
Review of runway extension length

Figure 2: 787-8 (B64) takeoff weights required and available

787-8 (B64) takeoff weight required WLG-PEK
121700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

787-8 (B64) takeoff weight required WLG-CAN
121700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS
Review of runway extension length

787-8 (B64) takeoff weight required WLG-LAX
121700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

Runway option/condition

787-8 (B64) takeoff weight required WLG-SIN
121700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

Runway option/condition
Review of runway extension length

Figure 3: 787-8 (B70) takeoff weights required and available
Review of runway extension length

787-8 (B70) takeoff weight required WLG-LAX
121900kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

- takeoff weight required max payload
- takeoff weight required max pax only
- takeoff weights available 21deg C 5kts head wind

Runway option/condition

787-8 (B70) takeoff weight required WLG-SIN
121900kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

- takeoff weight required max payload
- takeoff weight required max pax only
- takeoff weights available 21deg C 5kts head wind

Runway option/condition
Figure 4: 787-9 (B74) indicative takeoff weights required and available
Review of runway extension length

Figure 5: A330-800NEO takeoff weights required and available
Review of runway extension length
Figure 5a: A330-900NEO takeoff weights required and available
Review of runway extension length

A330-900NEO takeoff weight required WLG-LAX
136500kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

A330-900NEO takeoff weight required WLG-SIN
136500kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

Runway option/condition

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Astral Limited

Review of runway extension length

Figure 6: A350-900 takeoff weights required and available
Review of runway extension length
Review of runway extension length

Figure 7: A350-1000 indicative takeoff weights required and available
Review of runway extension length

A350-1000 takeoff weight required WLG-LAX
158400kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS
INDICATIVE DATA ONLY

- takeoff weight required max payload
- takeoff weight required max pax only
- takeoff weights available 21deg C 5kts head wind

Runway option/condition

A350-1000 takeoff weight required WLG-SIN
158400kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS
INDICATIVE DATA ONLY

- takeoff weight required max payload
- takeoff weight required max pax only
- takeoff weights available 21deg C 5kts head wind

Runway option/condition
Review of runway extension length

Figure 8: A330-200 takeoff weights required and available

A330-200 takeoff weight required WLG-PEK
125700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

- takeoff weight required max payload and max passengers
- takeoff weights available 21 deg C, 0kts head wind

Runway option/condition

A330-200 takeoff weight required WLG-CAN
125700kg OEW 100kg/pax, 5% fuel cty
SUMMER ENROUTE WINDS

- takeoff weight required max payload
- takeoff weight required max pax only
- takeoff weights available 21 deg C, 0kts head wind

Runway option/condition
Review of runway extension length
Review of runway extension length

Figure 9: A320-200 takeoff weights required and available
Review of runway extension length

![Graph showing takeoff weight required for A320 with IAE V2527 engines for various runway conditions and weights.]

**Takeoff weight required WLG-RAR**
A320 with IAE V2527 engines
45200kg, OEW 100kg/pax, 5% fuelcontingency
SUMMER ENROUTE WINDS

- Takeoff weight required max payload and max passengers
- Takeoff weight available

**Runway and condition**
- 15dry
- 16wet
- 34dry
- 34wet
- 16+355m dry
- 16+355m wet
- 34+355m dry
- 34+355m wet

![Graph showing takeoff weight required for A320 with IAE V2527 engines for various runway conditions and weights.]

**Takeoff weight required WLG-ADL**
A320 with IAE V2527 engines
45200kg, OEW 100kg/pax, 5% fuelcontingency
SUMMER ENROUTE WINDS

- Takeoff weight required max payload and max passengers
- Takeoff weight available

**Runway and condition**
- 16dry
- 16wet
- 34dry
- 34wet
- 16+355m dry
- 16+355m wet
- 34+355m dry
- 34+355m wet
Review of runway extension length

Figure 10: A320-200NEO takeoff weights required and available
Review of runway extension length

Takeoff weight required WLG-RAR
A320NEO with PW1127G engines
46040kg, OEW 100kg/pax, 5% fuel contingency
SUMMER ENROUTE WINDS

INDICATIVE DATA

Takeoff weight required max payload and max passengers

Takeoff weight available

Runway and condition

79500
79000
78500
78000
77500
77000
76500
76000
75500
75000
74500

16dry
16wet
34dry
34wet
16+355m dry
16+355m wet
34+355m dry
34+355m wet

Takeoff weight required WLG-ADL
A320NEO with PW1127G engines
46040kg, OEW 100kg/pax, 5% fuel contingency
SUMMER ENROUTE WINDS

INDICATIVE DATA

Takeoff weight required max payload

Takeoff weight required max passengers only

Takeoff weight available

Runway and condition

79500
79000
78500
78000
77500
77000
76500
76000
75500
75000
74500

16dry
16wet
34dry
34wet
16+355m dry
16+355m wet
34+355m dry
34+355m wet
Figure 11 A321NEO takeoff weights required and available
Figure 12: 777-200ER and 787-8 landing weights required and available
Figure 13: 787-9 landing weights required and available
Review of runway extension length

Figure 14: A350-900 and A350-1000 landing weights required and available
Review of runway extension length

Figure 15: A330-200 landing weights required and available
Figure 15a: A330-800NEO and A330-900NEO landing weights required and available
Figure 16: A320 and A320NEO landing weights required and available
Review of runway extension length

Figure 17: A321NEO landing weights required and available