RiverOak Strategic Partners

Review of Potential Noise Mitigation Measures

TR020002/D4/RPNMM

Examination Document

Project Name: Manston Airport Development Consent Order
Application Ref: TR020002
Submission Deadline: **4**
Date: 8 March 2019

Review of Potential Noise Mitigation Measures

Date: 8 March 2019

Author: Analyst

Revision: Version 3.1TR

Osprey Ref: 70992 11R

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Document Details

Reference	Description
Document Title	Review of Potential Noise Mitigation Measures
Document Ref	70992 11R
Issue	Version 3.1TR
Date	8 March 2019
Client Name	RiverOak Strategic Partners
Classification	

Issue	Amendment	Date
Version 1.5	Combination of two noise mitigation work streams and review	16 October 2017
Version 1.6	Adjustment of noise associated tables	18 October 2017
Version 2	Redacted Tech	26 February 2019
Version 3	Redacted version for release	7 March 2019
Version 3.1	Syntax corrections	8 March 2019

Approval Level	Authority	Name
Author	Osprey CSL	Analyst
Reviewer	Osprey CSL	Director

Executive Summary

This report considers a number of operational noise mitigation techniques that Manston Airport could consider to create a noise mitigation strategy. It represents a redacted version of the Commercial in Confidence document (Review of Potential Aircraft Noise Abatement Operational Procedures. Report 70992-011 Version 2.1 for RiverOak Strategic Partners 18 December 2017); removing commercially sensitive and proprietary analytical information. Elements of the analysis was conducted by Wood, when Amec Foster Wheeler (AFW). For continuity, the report continues to refer to AFW as the originator of the data.

The report found that based purely on meteorological factors, a preferential runway strategy would have a significant noise reduction effect and was feasible for the majority of the time (67.8%). The biggest limiting factor to preferential runway operations will be the movement rate that Manston Airport would like to be able to achieve. Above a movement rate of 5 freighter / airliner movements per hour, Manston Airport would no longer be able to support opposite runway direction operations.

Increased approach angles were also found to have a theoretical effect on the reduction of noise; however, evidence suggests that when actually undertaken, the more technically challenging approach may result in an increased level of aborted approaches nullifying noise benefits.

Abbreviations

Abbreviation	Meaning
AFW	Amec Foster Wheeler
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CAP	Civil Aviation Publication
DfT	Department for Transport
DT	Displaced Threshold
ICAO	International Civil Aviation Authority
JAA	European Joint Aviation Authorities
LDA	Landing Distance Available
LHR	London Heathrow
MLW	Maximum Landing Weight
MTOW	Maximum Take-Off Weight
MZFW	Maximum Zero Fuel Weight
PANS OPS	Procedures for Air Navigation Services – Air Operations
RAF	Royal Air Force
RNAV	Area Navigation
RSP	RiverOak Strategic Partners
SEL	Sound Exposure Level
SODROPS	Simultaneous Opposite Direction Runway Operations

Abbreviation	Meaning
STOL	Short Take-Off and Landing
TODA	Take-Off Distance Available

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1 Introduction

1.1 Background

Wood (when Amec Foster Wheeler (AFW)) has produced noise contours associated with predicted flights for Manston Airport. The analysis includes suggestions to mitigate the potential noise exposure to the local population in the event that Manston Airport is successful in its application to return to full operational status. RiverOak Strategic Partners (RSP) has requested Osprey review the noise mitigation techniques that could be employed in order to understand the potential impact to airport operations.

AFW proposed use of the following noise mitigation techniques for Manston Airport:

1. Inset Thresholds (of 100 metres (m), 250 m and 500 m);
2. Increase Runway Length (of 100 m, 250 m and 500 m);
3. Altering Approach Profiles;
4. Runway Preference; and
5. Night Flying restrictions.

Each of these noise mitigation techniques will be reviewed in detail in this report; however, this report will also consider limiting the use of reverse thrust on landing.

1.2 Additional factors

It should be recognised that, when considering such mitigation measures, there are a significant number of additional factors that have a direct bearing on their implementation:

- Firstly, while some may be combined (such as 'Inset Threshold' and 'Increased Runway Length') others may be *mutually exclusive* ('Inset Threshold' is likely to increase the potential use of reverse thrust, particularly on a wet runway).
- Secondly, different operators may have different restrictions or appetites on the use of some mitigation measures due to their own safety concerns (such as altering approach profiles). Any such measures will be subject to their internal Safety Management System (SMS) which may preclude or constrain when certain activities can be applied.
- Finally, even where an operator has accepted the use of a potential noise mitigation measure, the ultimate decision as to whether to actually implement it remains with the captain of the aircraft. For example, although Manston may have installed the infrastructure to enable steeper approaches, and an operator has approved their use through training, it is ultimately the captain's decision whether to elect for this or a conventional approach.

Therefore, while this study will consider the respective advantages and disadvantages of each option, it must be recognised that they may not be implemented universally, in chorus and consistently; this may have an impact on the actual benefit derived.

1.3 Our Methodology

To determine the merits of each of the noise mitigation techniques listed above the theoretical advantages of each were examined, and evaluated. Wherever possible a level of theoretical calculation was undertaken to evaluate whether the noise mitigation technique would be feasible at Manston Airport, and could be used as part of a wider noise mitigation strategy. No detailed safety analysis of the differing operational techniques was undertaken. The calculations were, where possible, based on data for Manston, such as Met Office historic wind and precipitation data, or where data is not readily available the experience of operational experts including pilots and air traffic controllers.

1.4 Amec Foster Wheeler Analysis

In parallel with this report Amec Foster Wheeler (AFW) undertook an analysis of environmental benefits of some of the noise mitigation techniques examined within this report. AFW have provided values for the number of people that would be adversely affected by aircraft noise (exposed to noise levels above the daytime or night time Lowest Observed Adverse Effect Levels (LOAELs) of 50 dB $L_{Aeq,\,16hr}$ and 40 dB $L_{Aeq,\,8hr}$ respectively) and significantly affected by aircraft noise (exposed to noise levels above the daytime or night time Significant Observed Adverse Effect Levels (SOAELs) of 63 dB $L_{Aeq,\,16hr}$ and 55 dB $L_{Aeq,\,8hr}$ respectively). These are provided for the year of maximum forecast capacity. For ease of comparison the AFW data has been converted into percentages based on a baseline of what is considered to be normal operations at Manston. Normal operations are considered to be no displacement of runway thresholds, and an aircraft approach angle of 3°.

Following the analysis of each noise mitigation strategy, the data from AFW has been evaluated to add further context to the analysis.

2 Inset Thresholds

2.1 Introduction

The runway threshold is the beginning of the portion of runway that is usable for landing. One proposed method of mitigating the impact of aircraft noise is to inset the runway threshold thereby moving the approach profile of an aircraft closer to the airfield and the aircraft touchdown point further down the runway. From a noise perspective, this means that aircraft fly at higher altitudes as they pass over communities located near the airport. In principle, the increased height and distance between aircraft and local communities reduce (abate) noise levels experienced on the ground.

Inset (or displaced) thresholds may offer scope to move the noise footprint of arriving aircraft closer to the airport by the same distance as the displacement. It is a well-established practice to inset runway thresholds to increase the clearance between approaching aircraft and obstacles located near the airport; it is less often used as a method of noise mitigation.

2.2 Potential Advantages of Inset Thresholds

In theory, inset thresholds take advantage of the better landing and stopping performance of modern aircraft. However, they equally artificially shorten the amount of runway available for landing; this could have potential impacts on safety, capacity and operational capability which must be measured against cost effectiveness and environmental benefit compared to alternative mitigation measures. This balance of benefit versus impact is reflected by the International Civil Aviation Organisation (ICAO) which prescribes the following criteria:

> *"The practice of using a displaced runway threshold as a noise abatement measure shall not be employed unless aircraft noise is significantly reduced by such use and the runway length remaining is safe and sufficient for all operational requirements."* (ICAO Doc 8168, Part I, Section 7, Chapter 3, Page 4, Subsection 3.6).

Because assessments against the ICAO criteria are site-specific, evaluation needs to be completed on a case-by-case basis. Any airport considering the use of inset runway thresholds as a noise abatement measure would need to conduct a similar analysis under ICAO criteria.

2.3 Potential Impact on Manston Operations

Table 1[1] below gives the declared distances that were utilised for the runway at Manston Airport before it closed. When Manston airport was last open the main runway length was 2,752 m; the 8th longest public runway in the UK.

[1] The data in this table is taken from VATSIM's Manston Airport vMATS Part 2. It is recognised that these figures are for a "virtual" Manston Airport, however VATSIM will wherever possible replicate the airfield data exactly.

RWY	Take-Off Distance Available (TODA[2]) (m)	Landing Distance Available (LDA[3]) (m)
10	3,169	2,752
28	3,112	2,752

Table 1 - Old Runway declared distances at Manston Airport

Introduction of an inset threshold will not impact the TODA, but will result in reduced LDA for the particular runway end. Table 2 below details the updated LDA for a given inset threshold for RWY 28.

Inset Threshold (m)	RWY 28 LDA (m)
100	2,652
250	2,502
500	2,252

Table 2 - LDA at Manston Airport for a given inset threshold

Table 3 below details the minimum landing distance required for aircraft types that are likely to operate from and to a reopened Manston Airport including:

1. Large cargo aircraft (e.g. 747, MD-11, 767, A380-800F);
2. Medium/Large commercial aircraft (e.g. A330);
3. International Short Haul (e.g. 737); and
4. Domestic regional aircraft (e.g. DASH8, Embraer ERJ190 and Bombardier CRJ900).

Aircraft	Minimum Landing Distance (Dry) Required[4] (m)	Wet Runway Minimum Landing Distance Required[5]
Boeing 747-400	1850	**2590**
Boeing 747-300	1800	**2520**
A380-800F	1650	**2310**
B767-300ER	1450	2030

[2] TODA – The length of the take-off run available plus the length of the clearway beyond the runway, where provided.
[3] LDA – The length of the runway that is declared available and suitable for the ground run of an aeroplane landing.
[4] These values are taken from aircraft characteristic manuals and are based on aircraft landing at sea level, in dry conditions and at 80% of their Maximum Landing Weight (MLW)
[5] Minimum Landing Distance multiplied by a factor of 1.4 taken which is recommended by the Flight Safety Foundation Approach and Landing Accident Reduction Toolkit

Aircraft	Minimum Landing Distance (Dry) Required[4] (m)	Wet Runway Minimum Landing Distance Required[5]
Bombardier CRJ900	1450	2030
B777-200ER	1400	1960
A330-300	1370	1918
Boeing 737-400	1400	1960
A320-200	1150	1610
A319-100	1100	1540
Embraer ERJ190	1100	1540
Dash 8 Q400	1000	1400

Table 3 - Landing distance required for aircraft types

The values calculated for this table indicate that all aircraft on this list would, in theory, be able to land at Manston Airport with a reduced runway length of 2,252m. However, these values are based on aircraft at 80% of their Maximum Landing Weight (MLW), landing on a dry runway. It can be seen that a wet runway would increase the Landing Distance required which would place restrictions on the aircraft using the runway; this will impact on those aircraft whose figures are shown in Red in Table 3. Equally, large freight aircraft may suffer restrictions on their useful payload in order to stay within the 80% MLW for adverse weather conditions. This could have further consequences as heavier aircraft may have to enter the hold and burn off additional fuel, adding unnecessary monetary and environmental costs, and aircraft suffering an emergency on take-off may not be able to land for an extended period of time. Smaller transport aircraft would be well within the parameters with even the larger threshold displacements considered.

2.4 Potential reduction in noise impact

The effectiveness of an inset threshold is directly linked to the reduction in noise over a given point, adjacent to the flight path. The reduction in noise will be directly linked to the increase in height over that point (assuming all other factors remain the same). To give an indication of the possible height increases as a result of an inset threshold, the increase in heights were calculated. A representation of this is shown in Figure 1.

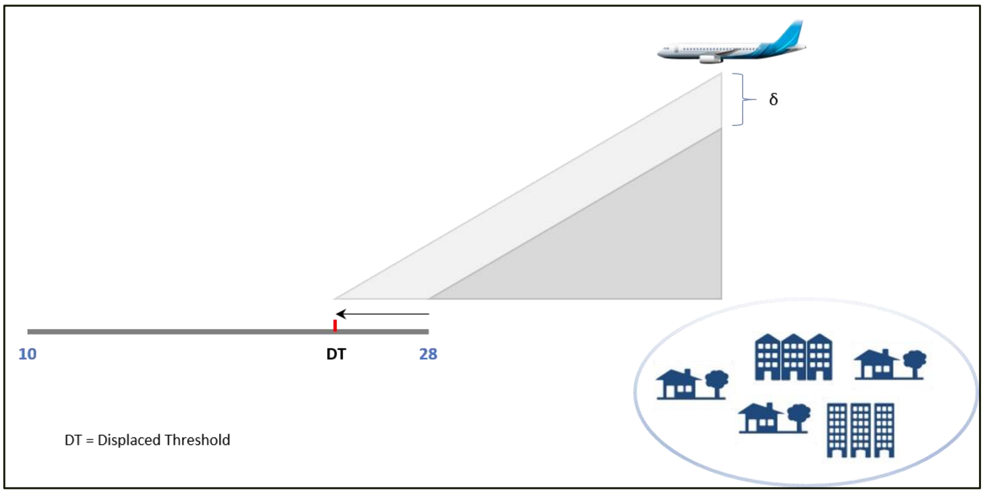

Figure 1 - Illustration of increased aircraft height over residential area due to an inset threshold

Referring to Figure 1, the following are the values for δ (the increase in height over a point on the ground) for each Displaced Threshold (DT) amount[6]:

1. Assuming a DT of 100 m, δ = 17ft
2. Assuming a DT of 250 m, δ = 43ft
3. Assuming a DT of 500 m, δ = 86ft

The differences in height, even with a 500m inset threshold, are very small, and the associated reduction in noise is likely to be modest.

In theory, sound pressure level (measured in decibels (dB)) decreases by 6dB when the distance from an object is doubled[7]. So, if a noise of 100dB is measured 1 m from the source of the sound, then 2 m away the sound pressure level would be 94dB. Utilising the data calculated in Figure 1; with an arbitrary sound pressure level of 50dB at 1,500ft then the sound pressure level at 1,586ft would be 49.5dB.

In an Insight Paper entitled Aviation Policy for the Environment, the CAA produced a graph to describe the effect of inset thresholds on the reduction of noise near London Heathrow Airport (LHR), shown in Figure 2 below:

[6] An approach angle of 3° is assumed and the overflight of the residential area is undertaken at 1,500ft during an approach.
[7] Source: http://hyperphysics.phy-astr.gsu.edu/hbase/Acoustic/invsqc.html#c1

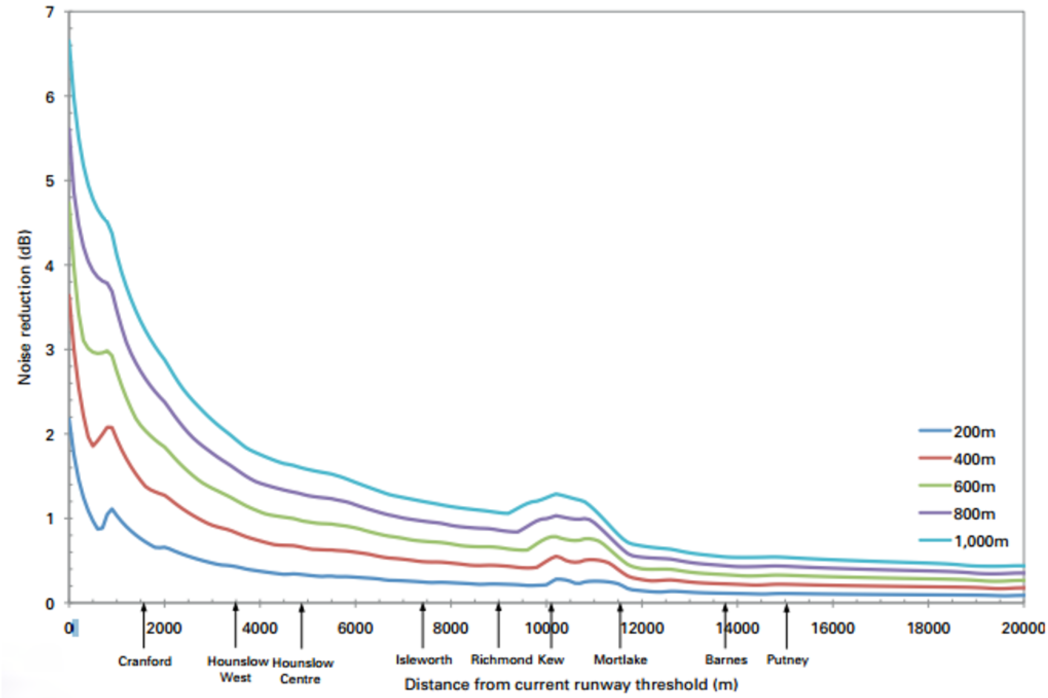

Figure 2 - Noise reduction resulting from implementing displaced thresholds at LHR

As this data is for LHR it cannot be used to make specific judgements about the effect of inset thresholds at Manston. However, it does show a clear trend from which parallels can be made, and it reinforces the concept that sound pressure level has an inversely exponential relationship with distance from a noise source. The graph clearly indicates that significant noise reductions can be made for an inset threshold of large displacements at the closest points to the airfield. For an inset threshold of 200 m, Figure 2 indicates that the noise reduction would be less than 1 dB within 1,000m from the runway. There are more significant reductions with a 1,000m inset threshold; however as previously discussed, this would put severe limitations on the operational capability of a reopened Manston Airport (reducing the LDA to just 1,752m).

2.5 AFW Data

The data produced by AFW relating to inset thresholds is shown in Table 4 below.

A baseline count of population exposed to noise levels above the daytime or night time LOAEL, and number of people exposed to noise levels above the daytime or night time SOAEL is calculated assuming a standard 3° approach is used to Runway 28 in its original configuration. Equivalent counts of the noise mitigation option are then compared to the baseline figure and given as a percentage. Whilst the percentages give an easy way to compare the changes it is important also to appreciate what that level of change represents, so the baseline numbers of people affected are shown and the change in numbers are shown for the displaced thresholds.

	Day		Night	
Inset distance	**Population exposed to noise greater than the LOAEL 50 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the SOAEL 63 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the LOAEL 45 dB $L_{Aeq,8hr}$**	**Population exposed to noise greater than the SOAEL 55 dB $L_{Aeq,8hr}$**
0	100% (34,540)	100% (774)	100% (42,584)	100% (1020)
100	100% (-48)	91% (-73)	100% (-116)	99% (-11)
250	100% (--60)	70% (-233)	99% (-377)	91% (-94)
500	99% (-474)	81% (-150)	98% (-796)	91% (-91)

Table 4 - Percentage of baseline levels for inset thresholds

The data in Table 4 shows the improvement on the population exposed to the LOAEL is small for all cases at day and night. The reduction in the number of people exposed to the SOAEL at day and night is greater, up to 19% in the day and 9% at night. The reduction in people exposed to noise greater than the SOAEL during the day does not increase with increasing inset threshold; a 250m threshold leads to a greater reduction in population exposed to the SOAEL during the day than a 500m threshold. This is due to the shape of the contours close into the airport and the distribution of the population around the airport.

2.6 Conclusion

Anything greater than a 500m inset threshold would have a significant impact on Manston operations, precluding the use of aircraft types that are universally used in the cargo fleet. Furthermore, a 500m inset threshold only results in an 86ft difference in aircraft height resulting in less than a 0.5dB reduction in noise at 500ft. The AFW data supports this analysis as the reduction in levels of annoyance and disturbance are minimal.

Although not directly comparable, the LHR study illustrates that the noise benefits of an inset threshold reduce significantly with distance; it implies that at 4000m, the distance between Manston's eastern threshold and the eastern edge of Ramsgate, any noise benefit would be reduced by 75%; even at 1400 m, the closest point between the western edge of Ramsgate and Manston's easterly threshold, the benefit is likely to have been reduced by 50%. Such an assessment does not meet the ICAO requirement that inset thresholds should only be used for noise abatement *if aircraft noise is significantly reduced and that the runway remains safe and sufficient for all operational requirements*.

3 Altering the Runway Length/ Declared Distances

3.1 Introduction

The aim of extending a runway's length would be to cater for an inset threshold without reduction of the LDA or increase use of reverse thrust. The TODA is less significant a factor as modern aircraft do not need the full runway length.

3.2 Cost of runway extension

The cost associated with extending a runway is far greater than simply the cost required for the construction of the runway itself. In addition to the runway, there is the potential for further infrastructure construction costs, including adjusting ground based radio navigation aids, airport lighting, and runway markings. A conservative estimate for purely the construction of a 500m runway extension would be in excess of £8M. This figure assumes that the land is available for development and other airport safeguarding criteria (set against other existing buildings or projects in the vicinity of the airport) can be met; for a westerly runway extension at Manston this would require the removal of around 30 properties at Smugglers Leap Park, the house on Mount Pleasant Road and the remodelling of the A253, the B2190 and the Minster Roundabout; these changes would add further significant costs.

3.3 Potential reduction in noise impact

As described previously, an inset threshold and associated runway extension of this size would result in a very marginal noise reduction. Consequently, although it would allow aircraft to operate at higher landing weight even in wet conditions, the potential cost of extending the runway from its previously used configuration would outweigh any benefits in terms of noise reduction.

4 Altering the Approach Profile

4.1 Introduction

The introduction of steeper approach profiles at an airport could be used to mitigate the noise effect of aircraft over noise sensitive areas. However, the associated impact on aircraft certification, pilot training, aircraft operator and airport infrastructure requirements, as well as the related cost to airport operational and regulatory changes must also be considered.

4.2 Regulatory Factors

The International Civil Aviation Organisation (ICAO) PANS-OPS Doc 8168 is the guidance material used for designing instrument approach procedures. Deviation from this guidance can only be authorised in the UK by the CAA. It requires that an aeronautical safety study is conducted for all approach designs steeper than 3.5° for larger aircraft (3.7° for small aircraft).

It further states:

> *"Glide path angles above 3.5° should be used in approach procedure design only for obstacle clearance purposes and must not be used as a means to introduce noise abatement procedures. Such procedures are non-standard and require a special approval".*

Flight operations are not impacted up to 3.5° but above this value additional design 'add-ons' are included. This may affect the aerodrome operating minima and restrict the ability of aircraft to land safely in poor weather conditions.

4.3 Aircraft Certification Requirements

Some aircraft that are optimised for Short Take-off and Landing (STOL) performance can fly steeper approaches safely and within certification requirements; it is not anticipated that such aircraft will regularly operate from Manston. For larger aircraft, the limits may be close to the standard 3.0° approach angle. However, while steeper approaches may be feasible from an aircraft certification perspective, they may introduce operational limitations associated with Instrument Landing System (ILS) Category II and III approaches and automatic landing systems (Autoland). Area Navigation (RNAV[8]) approaches do present the possibility of introducing steeper approaches without the cost of changing ground-based infrastructure; although there would be a cost associated with designing new procedures. However, before considering steep approach operations, the airport should first determine the limitations on the aircraft that regularly use the airport and any potential types that may operate from there in the future as this may preclude their operation or constrain future growth.

[8] RNAV – A method of navigation without the need of transiting from one radio beacon to another

4.4 Pilot and Operator Requirements

Pilots can fly steeper approaches if the aircraft is appropriately certificated. It should be possible to accommodate approaches of up to 3.5° without additional training. For approaches steeper than 3.5°, the aircraft operator may incur additional training costs associated with that airport, potentially making an airport less attractive compared with its competitors. Care must be taken not to allow steeper approaches which result in an increase in the aerodrome operating minima for an airport as this could have knock on consequences and costs for aircraft operators. Changes should be subject to a full safety analysis for the operational effects to aircraft operators.

4.5 Airport Operational Implications

The introduction of a steeper approach can affect how aircraft crews choose to fly the approach in terms of airspeed, flap and landing gear configuration and deceleration. These variations of aircraft configuration and flight profile can increase the frequency that missed approaches, or go-around procedures are flown and impact on the landing/departure rate for the runway as well as increasing fuel burn and CO_2 emissions.

Not all aircraft captains will be capable of, or willing to, fly a steeper approach. There is therefore a need to also retain a conventional 3° approach. This will result in some duplication of infrastructure as aerodrome lighting and markings will have to be provided for both approach angles. There is equally a risk that pilots may use the incorrect systems for their chosen approach angle. Finally, there will need to be a capability for mixed mode operations (both steeper and normal approaches) which will reduce any benefits from having a steeper approach option.

4.6 Aircraft Speed

An approach slope of 3.2° was used in part of a trial at Frankfurt Airport. This slope value was used as it was determined that A320 and A330 aircraft could fly the approach with the same flap setting as a 3.0° approach. Above this an additional flap setting would be needed which would potentially increase the noise impact closer to the airport. One of the findings of the trial was that the aircraft flew the steeper approach slightly slower. Unfortunately, the trial did not provide reports from pilots to determine why this reduced speed was exhibited. For steeper approaches an aircraft is more difficult to decelerate so a pilot will choose to start the approach slower, or adjust how much flap is used, or select the landing gear at a different point on the approach, which will affect the noise profile of the approach. Given that airports like Frankfurt issue Air Traffic Control (ATC) speed instructions to pilots it is likely that pilots were choosing to fly the aircraft as slow as they could and still be within the ATC requirements.

At busy airports ATC use speed instructions to control the arrival spacing between different aircraft. They may instruct an aircraft to reduce its speed to maintain separation from the one ahead or instruct an aircraft to slow down if they wish to instruct another aircraft to take-off before the approaching aircraft lands. If the increase in approach angle makes the aircraft more restrictive in terms of the speeds it can fly, and/or its ability to quickly adjust the speed, it can reduce the ability of ATC to manage the safe and expeditious flow of air traffic.

4.7 Tailwind tolerance

Generally, aircraft land in the runway direction that gives a headwind component as it allows the aircraft to touchdown at a slower speed and reduce the landing distance. However, at many airports it is often advantageous to accept occasional landings with a tailwind component if operationally acceptable. For instance, the wind may change direction during a particular busy period of operations, and it is better to wait to change runway direction when the movement rate reduces as there is some disruption during the process of swapping runway ends.

With steeper approaches, the ability for some aircraft to cope with a tailwind during the approach is reduced. The aircraft may need to use more flap setting, which produces more noise. It may need to slow down earlier which could change noise levels at different points along the approach. This would affect one of the other proposed noise mitigation measures; selection of runway direction for noise abatement.

For these reasons, it is likely that any increased approach angle should be in addition to the retained provision of a 3.0° approach. However, this would require pilots to correctly identify when they are not able to complete the steeper approach. The consequences of an incorrect decision could be a noisier approach or an approach that did not attain the correct airspeed before landing which would require the aircraft to conduct a go-around/missed approach procedure (which would create additional noise, a delay, and increased fuel burn).

4.8 AFW Data

The data from AFW for increased approach angles to Runway 25 is shown in Table 5 below:

	Day		**Night**	
Angle of Approach	**Population exposed to noise greater than the LOAEL 50 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the SOAEL 63 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the LOAEL 45 dB $L_{Aeq,8hr}$**	**Population exposed to noise greater than the SOAEL 55 dB $L_{Aeq,8hr}$**
3°	100% (34,540)	100% (774)	100% (42,584)	100% (1020)
3.2°	100% (+67)	75% (-190)	100% (0)	100% (0)
3.5°	98% (-791)	9% (-708)	98% (-829)	14% (-882)

Table 5 - Percentage of baseline levels for increased approach angle

The data in Table 5 suggests that there is 1 – 2% reduction in the population exposed to noise levels above the LOAEL. Large reductions are demonstrated for the population exposed to noise levels above the SOAEL, particularly with a 3.5° approach angle. While the numbers suggest this would be a particularly beneficial noise mitigation strategy for the population close to the airport; the numbers provided assume that all aircraft carry out the same type of approach. This will not be the case as only a percentage of aircraft will undertake a 3.2° or 3.5° approach, so the reduction in numbers affected would not be so large. The benefits of steeper approaches must also be compared with the noise reduction benefits of a preferential runway strategy because the increased approach angles limit the tailwind tolerances of aircraft on approach and therefore the ability to operate a preferential runway strategy. Also, as described earlier, the use of steeper approach angles can increase the number of aborted approaches which would actually increase the noise levels experienced. This factor has not been captured in the AFW analysis.

It should also be noted that, at present, no conventional airport operates such a steep approach. However, if steeper approaches are introduced routinely at conventional airports it is anticipated that it will be in the region of 3.2°, the slope angle used in previous limited trials. A 3.5° approach angle would make Manston unique in conventional airports, potentially making it less attractive to operators.

4.9 Combining Steeper Approaches and an Inset Threshold

For completeness, the possibility of combining noise abatement options should be considered. An analysis of the steeper approach profiles suggests that it would be reasonable to consider a 3.5° approach as the steepest achievable whilst maintaining standards of safety and not prohibiting operations.

Using the same parameters as in Figure 1 but with an approach angle of 3.5° the increased height due to a DT would be as follows:

1. Assuming a DT of 100 m, δ = 20ft
2. Assuming a DT of 250 m, δ = 50ft
3. Assuming a DT of 500 m, δ = 100ft

The results above suggest that even combining inset thresholds with steeper approach profiles would not significantly reduce the noise profile. Equally, the proposition to complete a steeper approach to a foreshortened runway would not meet the ICAO requirement of ensuring that runway length is '*safe and sufficient for all operational requirements*'.

4.10 Further AFW Data

AFW has also provided data for a scenario in which Runway 28 has been extended to facilitate an inset threshold of 500m without affecting the LDA. This runway scenario was then analysed to compare the effects of increased approach angles. The data for this analysis is in Table 6 below:

	Day		Night	
Angle of Approach	**Population exposed to noise greater than the LOAEL 50 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the SOAEL 63 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the LOAEL 45 dB $L_{Aeq,8hr}$**	**Population exposed to noise greater than the SOAEL 55 dB $L_{Aeq,8hr}$**
Normal Operations[9]	100% (34,540)	100% (774)	100% (42,584)	100% (1020)
3°	97% (-956)	18%(-638)	98% (-977)	32% (-694)
3.2°	97% (-956)	8.5% (-708)	98% (-977)	23% (-788)
3.5°	98% (-791)	8.5% (-708)	98% (-829)	14% (-882)

Table 6 - Percentage of baseline levels for extended runway, displaced threshold and increased approach angle

Table 6 indicates that once again an increased approach angle in combination with an extended runway has a small change in the number of people exposed to the LOAEL. Again a large percentage change in the number of people exposed to the SOAEL is demonstrated.

[9] In the Normal Operations scenario, the runway has not been extended, there is no displaced threshold and aircraft approach at an angle of 3°.

5 Runway Preference

5.1 Introduction

Normally the *runway-in-use* is selected to most closely align to the prevailing surface wind direction. If the surface wind is light and variable then the principal consideration should be the 2,000 ft wind in the vicinity of the airport. Other factors that will be considered when selecting the runway-in-use include local adjacent air traffic patterns, the length of runways available, position of the sun, or moon, the approach aids available and other prevailing meteorological conditions.

Figure 3 below provides a simplified flow diagram of an airport using the conventional single runway operations where the same runway direction is used for departures and arrivals; Figure 4 shows the issues associated with departures and arrivals from opposite direction runways.

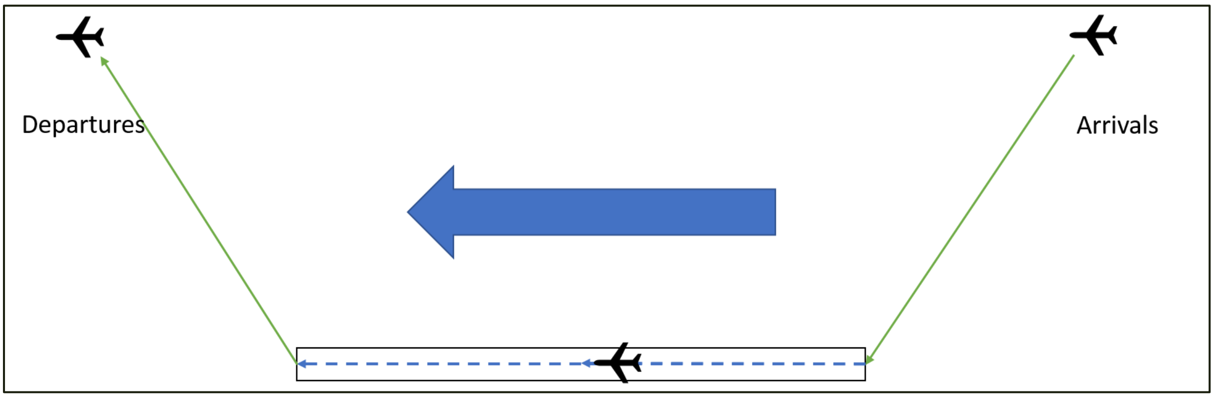

Figure 3 - Diagram demonstrating same runway operations

5.2 Selecting Runway preference

Whenever possible pilots would prefer to land into a headwind. The advantage of landing in a headwind is that the relative speed of the air over the wing is higher; generating more lift, meaning an aircraft can approach a runway at a lower ground speed. This will have the effect of reducing the length of runway required when landing.

A tailwind will have the opposite effect. The relative speed of the air over the wing is lower, so the aircraft will have to approach the airfield at a higher ground speed. This will have the effect of increasing the length of runway required, landing distance, as the aircraft will be travelling faster when it lands.

CAP 493 gives guidance on the constraints for selecting a runway for noise abatement purposes. It states:

> *"Noise abatement shall not be the determining factor in runway nomination, when it is known that the crosswind component, including gusts exceeds 15kt, or the tailwind component, including gusts exceeds 5kts."*

This statement implies that a runway should only be selected for noise abatement if the tailwind is 5kts or less. This report will examine runway length required with a tailwind of 5kts.

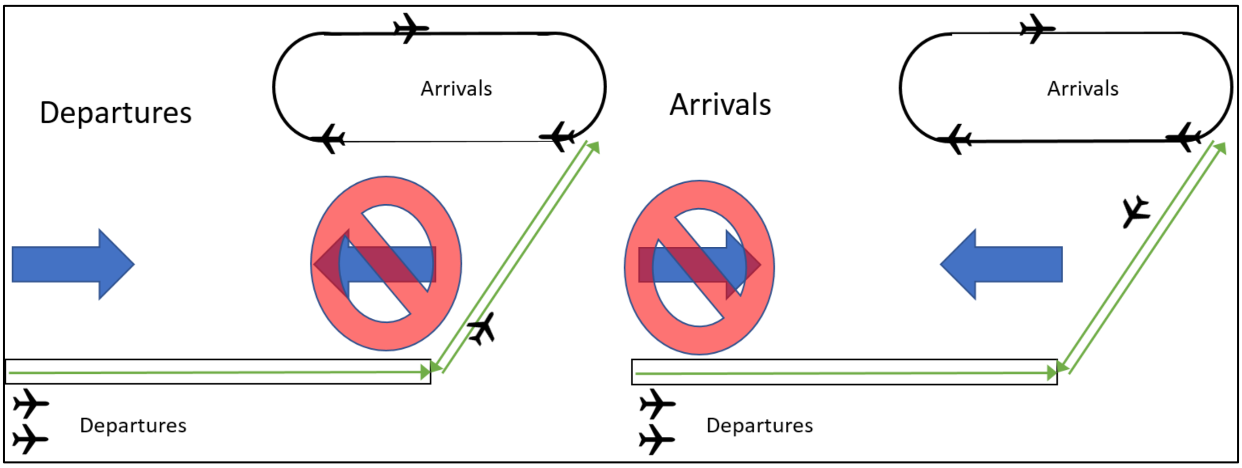

Figure 4 - Diagram demonstrating opposite direction runway operations on the same runway

Utilising a runway in deference to the ideal wind conditions has the risk of causing a higher rate of unsuccessful landings, increasing the number of aircraft forced to conduct a circuit to attempt a successful landing or executing a Missed Approach Procedure. Any of these events would undermine the noise reduction benefits associated with preferential runway selection; indeed, they could make them significantly worse with aircraft operating at high power settings in close proximity of the airport.

5.3 Application at Manston

The town of Ramsgate is located to the east of Manston Airport, and a large area of predominately agricultural land is located to the west. To limit the noise experienced by the residents of Ramsgate it would be ideal to operate with aircraft landing from, and taking off to, the west. That said, this must be balanced against any impact on other conurbations such as Herne Bay.

Utilising one runway for arrivals and the opposite runway for departures can create significant operational challenges. For these kinds of operations, the airspace utilised for departures and arrivals is the same and therefore only one action can take place at any one time, whereas in conventional operations departures and arrivals can be safely separated. This will dramatically reduce the flow-rate of an airport and lead to an increased workload for ATC as aircraft may be required to join a holding pattern on arrival or wait extended periods for a departure window. This is particularly the case at Manston where taxiway configurations may limit aircraft moving from their parking stand until a landing aircraft has cleared the runway. That said, it is anticipated that periods of lower intensity of operation, may allow such measures to be accommodated with little operational impact. Equally, the respective positioning of the conurbations of Ramsgate and Herne Bay would mean that the impact of such measures may be significantly different; little can be done to operationally mitigate the impact of aircraft departing and arriving over Ramsgate, less than 2 miles from Manston runway and directly under its centreline, whereas it is anticipated that departures to the west will turn before Herne Bay and arrivals from the west will fly over Herne Bay at approximately 2,500ft with low power settings. It is therefore anticipated that operational impact associated with considering noise abatement as one factor in deciding runway direction at Manston could be managed. This could also allow the noise experienced by local residents to be more pro-actively managed than previously.

5.4 Manston Preferential Runway Strategy

As mentioned in Section 5.3, the preferred runway option for Manston Airport would be for aircraft to land on Runway 10 and take-off from Runway 28 (aircraft landing from, and taking off to, the west), however this will not always be achievable due to prevailing wind and runway conditions and would have to revert to conventional runway utilisation if:

1. The movement rate (intensity) required is too high to be supported by opposite direction operations;
2. The tailwind component is too high for landing on Runway 10;
3. The tailwind component is too high for take-offs on Runway 28;
4. Wet or contaminated runway conditions necessitates the use of reverse thrust, in which case Manston Airport would have to operate on the in-to-wind runway.

For preferential runway operations to be a successful noise mitigation strategy it is important to see how much of the time Manston Airport could operate in this mode. To do this, Manston Airport's critical movement rate (utilising opposite direction operations) must be ascertained and what percentage of the time the prevailing weather conditions preclude a preferential runway strategy.

5.5 Movement Rate

Movement rate can be an important factor in the success of an airport. In 2013 London Gatwick Airport, the world's busiest single-runway airport, could handle 54 movements per hour. Critically this means that each aircraft has about one minute of the runway's time before the runway needs to be utilised again. This number of movements per hour is reached by slick operational processes and the advantage of aircraft landing and departing in the same direction.

As alluded to in Section 5.2, an airport that utilises opposite direction operations will not be able to reach this rate. This is because, the airspace that departing and landing aircraft utilise is the same and the aircraft will need to be carefully managed on the ground to ensure flow is maintained, so there needs to be extended built in separation between aircraft movements.

The limiting factor for the movement rate of opposite direction operations at Manston Airport will be ensuring that aircraft are not delayed in the air. Whilst it is conceivable that an aircraft may have a delayed start time to facilitate opposite direction operations, aircraft operators would not accept delays in the air, which could lead to large fuel consumption costs.

To determine a theoretical maximum movement rate at Manston Airport the following must be considered:

1. The time taken for an aircraft to complete the final stages of approach;

2. The time taken for that aircraft to land, exit the runway and taxi to a stand;
3. The time taken for a departing aircraft to taxi to the runway; and
4. The time taken for that aircraft to take-off, and vacate the approach lane to facilitate the next approach.

Due to proprietary sensitivities, the precise details of how the aircraft movement rate has been calculated have been redacted from this report. However, traffic modelling included the following:

- Aircraft approach speeds;
- Aircraft departure speeds;
- Track miles flown on approach and departure;
- Time taken for aircraft landing and taking off to clear the runway;
- Respectively calculating approach and departure flightpaths and speeds;
- Aircraft taxi speeds;
- Aircraft taxi routes and distances taxi times and speeds.

As a result of this modelling and analysis it has been calculated that, from a purely operational perspective, Runway Preference criteria could potentially be applied when the movement rate is 5 movements or less per hour. However, it must be reiterated, that there are a range of other factors including wind, runway condition and operational approval which would also need to be taken into account.

Due to the nature of the taxiway infrastructure at Manston Airport, when an aircraft is on approach, aircraft will not be able to taxi out as, with only one exit from either runway end, there is insufficient space for an inbound aircraft and an outbound aircraft to taxi simultaneously. As a result, the time it takes for an aircraft to taxi in, and then for the next aircraft to taxi out must be considered, sequentially, in the calculation of the movement rate.

5.6 Prevailing Wind Conditions

Sections 5.2 gave an indication of the parameters in which a preferential runway strategy could be used. This section will use historical Met Office data to explore when the prevailing wind conditions will allow for preferential runway operations. As stated in Section 5.2, there are constraints on the amount of tailwind that is allowable for purely noise abatement purposes, and it may also be the case that individual aircraft operators will have stricter tailwind constraints due to the increased risk associated with tailwind flight operations.

5.6.1 Wind Components

Ten years of wind data was used to gain a comprehensive understanding of the average wind speed and direction at Manston Airport. Fortunately, whilst RAF Manston and later Kent International Airport closed, the climate station has remained active so the data received is accurate for the proposed Manston Airport site.

The data received details the wind direction and speed, however this report is most concerned with the tailwind component. Wind has both speed and direction, and so like any other vector can be considered as two components working at right angles to each other. These components can be considered as the headwind/tailwind component and the crosswind component as described in Figure 5 below.

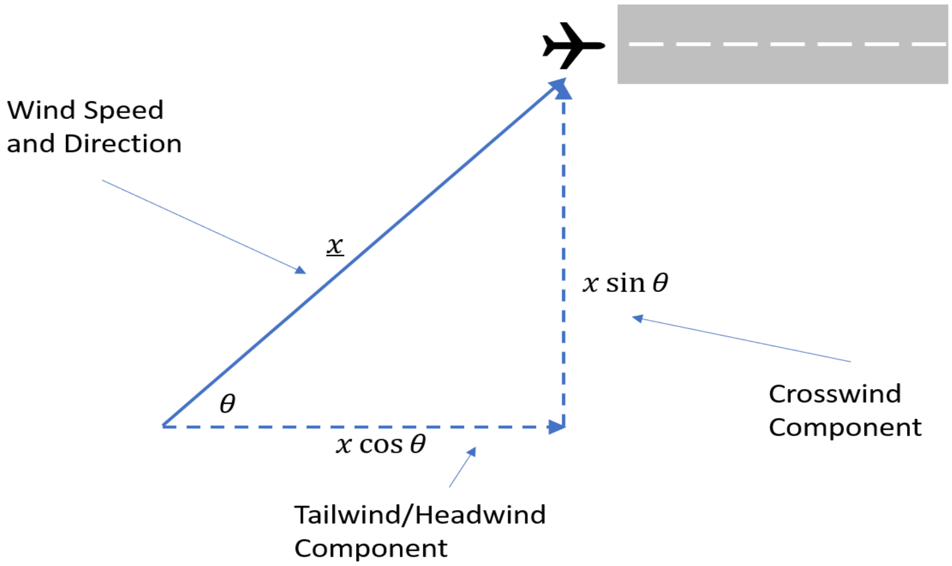

Figure 5 - Wind components for an aircraft approaching a runway

Figure 5 demonstrates that wind can always be broken down into a crosswind, and a tailwind/headwind component. Following a review of preferential runway strategies, it was determined that, for the purposes of analysis, 5kts should be the tailwind threshold for aircraft on landing and take-off. The data received from the Met Office was therefore evaluated to determine the percentage of time Runway 10 can be used for landings, and Runway 28 for take-offs, where the tailwind component is less than 5kts.

5.6.2 Met Office Data

The Met Office data comes in the form of a wind rose that shows the percentage of time wind is at certain speeds and directions. An example of a Manston climate station wind rose is shown at Figure 6. This wind rose shows the percentage of time (0 to 20% in Figure 6) the wind was in a given direction and at what speed. This data is taken from January 2006 to December 2015, so it gives a comprehensive assessment of normal wind characteristics at Manston.

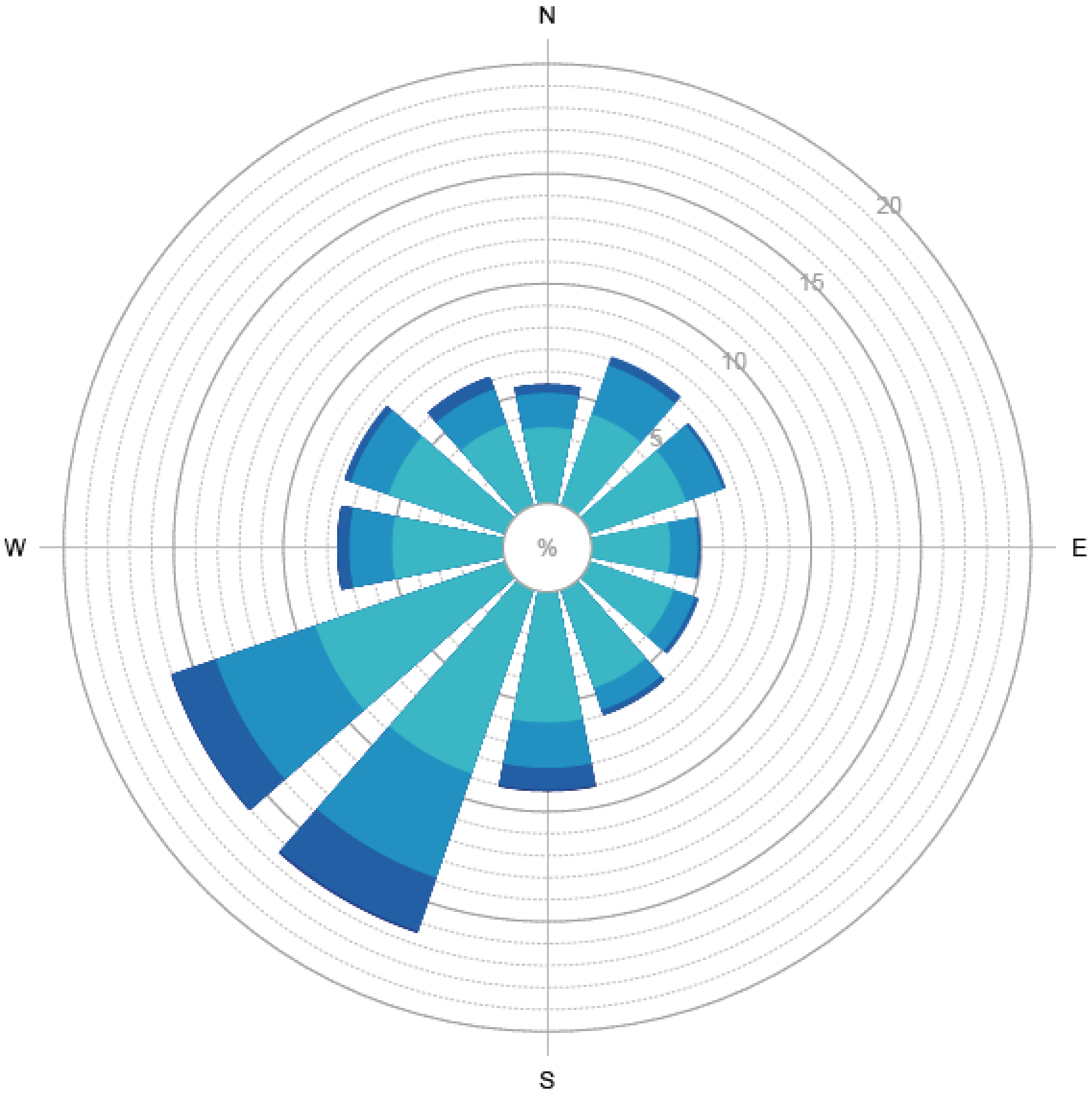

Figure 6 - Manston Wind Rose

The wind rose divides wind into 30° sections, and further subdivides the wind to indicate what percentage of the time it is within speed parameters, 1-10kts, 11-16kts, 17-27kts and 28-33kts.

5.6.3 Methodology and Assumptions

Wind speed and direction is in a state of near continuous change and it would be very difficult to assess raw wind data. For the purposes of analysis each wind rose section (a 30° wedge), is considered to be equivalent to all the wind being focussed through the centre of the section. For example, wind that is in the N section refers to wind in the direction 345° to 015°, however it is considered to be focussed in one direction as shown in Figure 7.

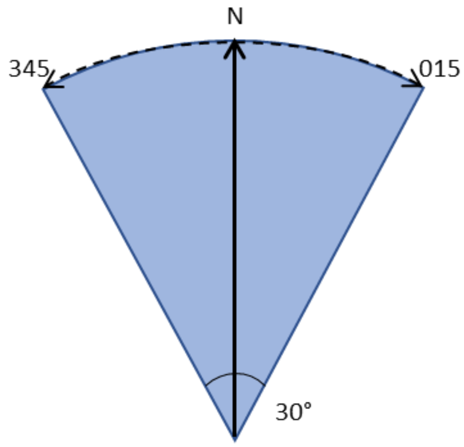

Figure 7 – Averaged Wind Range

In the same way as the wind direction, an assumption must be made about the wind speed. The Met Office data separates wind data into categories 1-10kts, 11-16kts, 17-27kts and 28-33kts, however the data gives no indication of how the wind speed is distributed within the category. To simplify the analysis, an assumption has been made that the wind speed distribution within each category is equivalent to the average wind speed value within that category. The wind speed used for each category is summarised in Table 7 below.

Wind Speed Category	Wind Speed Used for Analysis
1-10kts	5.5kts
11-16kts	13.5kts
17-27kts	22kts
27-33kts	30.5kts

Table 7 - Wind Speeds used in calculations

The wind rose data was analysed to determine the percentage of time that the wind at Manston is within each wind speed category. The results are summarised in Table 8 below.

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
1-10kts	3.42	4.34	4.61	3.55	3.95	4.74	5.92	8.82	9.08	5.00	5.53	3.95
11-16kts	1.58	2.37	1.71	1.32	1.05	1.05	2.11	5.00	4.74	2.11	1.84	1.71
17-27kts	0.26	0.39	0.13	0.13	0.26	0.26	1.05	2.63	2.11	0.53	0.39	0.53

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
28-33kts	0.00	0.00	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00

Table 8 - Percentage of time wind is at given speed and direction

The original Met Office data states that the wind at Manston is idle for 0.1% of the time, so the data in Table 8 above should add up to 99.9%. The percentages total 98.29% due to rounding errors during analysis of the original data.

Using the average wind speed for each category, we can first determine what the tailwind component, near the runway, of each wind speed and direction is, and then use Table 8 to determine what percentage of the time the tailwind component is above a given level.

5.6.4 Landing on Runway 10 with a 5kts tailwind

The tailwind component for the wind speeds given in Table 7 for Runway 10 is shown in Table 9 below. When the tailwind component is greater than 5kts it has been highlighted red.

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
1-10kts	0.96	-1.88	-4.21	-5.42	-5.17	-3.54	-0.96	1.88	4.21	**5.42**	**5.17**	3.54
11-16kts	2.34	-4.62	-10.34	-13.29	-12.69	-8.68	-2.34	4.62	**10.34**	**13.29**	**12.69**	**8.68**
17-27kts	3.82	-7.52	-16.85	-21.67	-20.67	-14.14	-3.82	**7.52**	**16.85**	**21.67**	**20.67**	**14.14**
28-33kts	**5.30**	-10.43	-23.36	-30.04	-28.66	-19.61	-5.30	**10.43**	**23.36**	**30.04**	**28.66**	**19.61**

Table 9 - Tailwind components for Runway 10

Combining the data in Table 8 and Table 9 it can be shown that the tailwind component for landings on Runway 10 will be greater than 5kts for 27.12% of the time, as shown in Table 10 below (the sum of the filled grid boxes).

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
1-10kts										**5**	**5.53**	
11-16kts									**4.74**	**2.11**	**1.84**	**1.71**
17-27kts								**2.63**	**2.11**	**0.53**	**0.39**	**0.53**
28-33kts	**0.00**							**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Table 10 - Percentage of time tailwind is greater than 5kts on Runway 10

5.6.5 Take-Offs from Runway 28 with a 5kts tailwind

The tailwind component for the wind speeds given in Table 7 for Runway 28 is shown in Table 11 below. When the tailwind component is greater than 5kts it has been highlighted in green.

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
1-10kts	-0.96	1.88	4.21	5.42	5.17	3.54	0.96	-1.88	-4.21	-5.42	-5.17	-3.54
11-16kts	-2.34	4.62	10.34	13.29	12.69	8.68	2.34	-4.62	-10.34	-13.29	-12.69	-8.68
17-27kts	-3.82	7.52	16.85	21.67	20.67	14.14	3.82	-7.52	-16.85	-21.67	-20.67	-14.14
28-33kts	-5.30	10.43	23.36	30.04	28.66	19.61	5.30	-10.43	-23.36	-30.04	-28.66	-19.61

Table 11 - Tailwind components for runway 28

Combining the data in Table 8 and Table 11 it can be shown that the tailwind component for take-offs on Runway 28 will be greater than 5kts for 13.94% of the time, as shown in Table 12 (the sum of the filled grid boxes).

Wind Speed	Wind Direction											
	000	030	060	090	120	150	180	210	240	270	300	330
1-10kts				**3.55**	**3.95**							
11-16kts			**1.71**	**1.32**	**1.05**	**1.05**						
17-27kts		**0.39**	**0.13**	**0.13**	**0.26**	**0.26**						
28-33kts		**0.00**	**0.00**	**0.00**	**0.00**	**0.07**	**0.07**					

Table 12 - Percentage of time tailwind is greater than 5kts

5.7 Wet Runway Conditions

The European Joint Aviation Authorities (JAA) define a runway as wet when:

> *"The runway surface is covered with water or when there is sufficient moisture on the runway surface to cause it to appear reflective, but without significant areas of standing water"*

To determine how often the runway at Manston would be wet is very difficult based on historic Met data because there are many factors involved. Data can show how much rain fell over the course of one hour, but will not give any indication of the intensity of downpour. The intensity of the rainfall can be as important as the amount of rain that fell and the runway's capacity to drain will also have a big impact on how often a runway will be considered wet. For example, there could be a large total amount of rainfall on a given day, but that amount fell over the course of the whole day, so the runway's drainage was able to manage the volume, stopping the runway from ever becoming wet. On the other hand, a brief thunderstorm could result in less total rainfall but produce so much rainfall in a short period of time that the runway drainage could not cope, resulting in a wet runway.

5.7.1 Historic Rainfall Data

To determine how often a wet runway would preclude Mode 1 operations, assumptions must be made on when the historic Met data denotes that the runway is wet. The data used for this analysis details the total rainfall per hour at Manston for the year 2016 as shown in Figure 8 below:

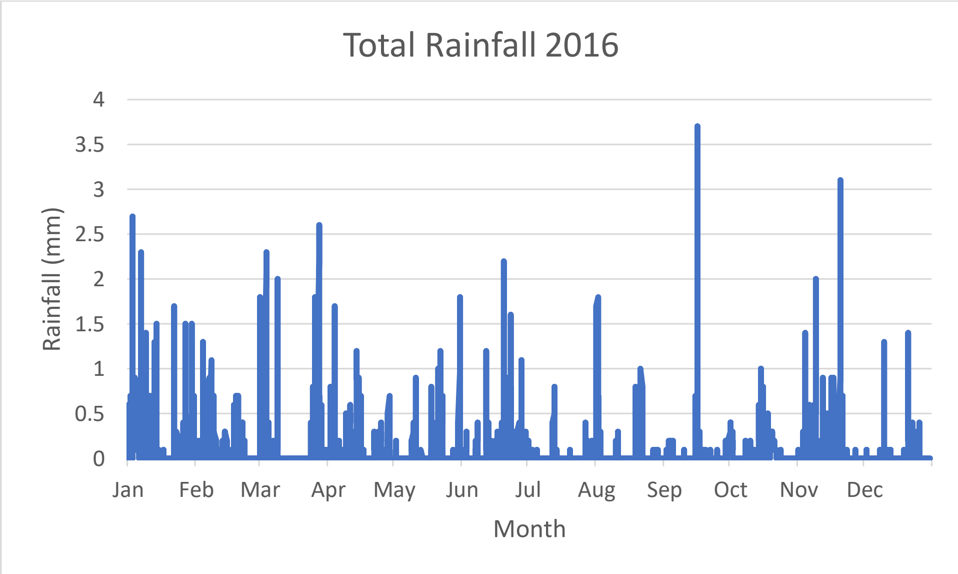

Figure 8 - Bar Chart of Manston Total Rainfall 2016

For the purposes of this report the level of rainfall required to make the runway wet needs to be defined in terms that align with the data. The Manston runway would be deemed to be wet if the amount of rainfall is equal to 2mm in the hour chosen and the preceding hour combined. By stipulating that the rainfall total is dependent on the previous hour, and using the Figure 8 data, allows for the possibility that a wet runway can be caused by an intense downpour or a more prolonged albeit less intense rain event. This does not consider any other weather conditions including temperature or wind conditions that would have an effect on the speed at which a runway is able to dry.

Using this as the definition for a wet runway indicates that there would be a total of 109 hours over 2016 in which the runway would be considered wet, as shown in Figure 9 below. 109 hours is equivalent to 1.24% of the year 2016, so Mode 1 would be unfeasible due to the runway being wet for 1.24% of the time. In discussion with operational experts this figure seems to be lower than expected, and it was felt that the correct figure would most likely be in the region of 1-5%.

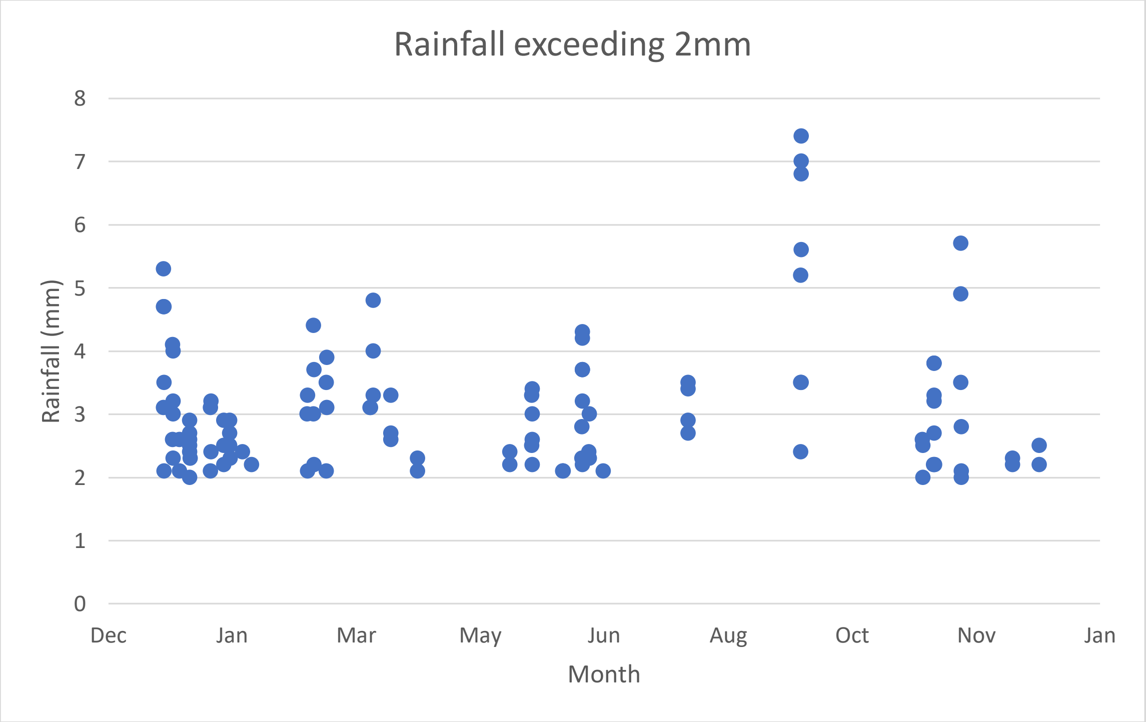

Figure 9 - Graph showing hours where rainfall exceeds 2mm

5.8 Reverse Thrust

Figure 10 - Pivoting-door thrust reversal on an A340-300

Reverse thrust is one of the major causes of noise for aircraft on the ground. It is used as a method of slowing down an aircraft, once landed, by temporarily diverting the aircraft engine's thrust so that it is directed forwards, rather than backwards. One method of noise mitigation used at an airport is to have a policy to discourage the use of reverse thrust. On dry runways the operational impact of such a policy is not very significant; however, on wet or contaminated runways the reverse thrust is more critical to decelerating the aircraft as the wheel brakes are less effective.

Many airports operate a reverse thrust minimisation policy. Usually the policy states that to minimise the disturbance in areas adjacent to the aerodrome, captains are requested to avoid the use of reverse thrust after landing, consistent with safe operation of the aircraft, between specified timeframes, most usually at night. To determine whether a similar policy can be utilised at Manston Airport, this report will examine if a reverse thrust policy could be instigated, by a comparison of the landing lengths required for different aircraft types, and under what conditions it should be utilised.

Generally speaking aircraft operations do not take account of the use of reverse thrust for landing calculations for dry runways. It can therefore be assumed that if an aircraft operator calculates that the aircraft can be landed on a dry runway then it can be done, under normal circumstances, without the use of reverse thrust. For runways that are wet or contaminated (standing water/snow/slush) then it is more likely, or even essential, to use reverse thrust on landing. Landing on a wet or contaminated runway with a tailwind will increase the likely use of reverse thrust or even preclude a landing on safety grounds. Based on these safety reasons and the extra noise for nearby residents, tailwind landings on wet runways will not be considered. In summary, on dry runways reverse thrust should not need to be used even with the tailwinds and on wet runways the use of reverse thrust would be required (or at least planned to be used), but minimised by landing into wind.

5.8.1 Effect of Tailwind on Landing Length Required

Calculating the effect of tailwind on required landing length is complex and for simplicity a predetermined factor is often used. The Flight Safety Foundation's Approach and Landing Accident Reduction toolkit[10] recommends using a factor of 1.2 for tailwinds up to 10kts, and this factor will be used for the purposes of this report.

To determine whether reverse thrust is likely to be needed on landing at Manston Airport the runway length was compared to the landing length required for a selection of aircraft types, likely to use the airport, at 80% of their Maximum Landing Weight (MLW), in calm conditions and with a tailwind of 5kts or less. The results are shown in Table 13 below:

[10] www.skybrary.aero/bookshelf/books/867.pdf

Aircraft	80% Maximum Landing Weight (kg)	Runway Length Required (m)[11]	Distance remaining from full runway length in dry conditions	Distance remaining from full runway length with a tailwind
Boeing 747-300	228,560	1,800	952	592
Boeing 747-400 Freighter	241,674	1,850	902	532
Airbus A380-800F	316,000	1,650	1,102	772
Airbus A330-300	148,000	1,370	1,382	1108
Bombardier CRJ900	26,672	1,450	1,302	1012
Boeing 777-200ER	178,534	1,400	1,352	1072
Boeing 767-300ER	116,120	1,450	1,302	1012
Boeing 737-400	44,996	1,400	1,352	1072
Airbus A319-100	50,240	1,100	1,652	1,212
Airbus A320-200	51,600	1,150	1,602	1,142
Embraer ERJ190	34,400	1,100	1,652	1,432
Bombardier Dash 8 Q400	23,223	1,000	1,752	1552

Table 13 - Comparison of landing distance required at 80% MLW

[11] This data is taken from the Airport Planning Manuals for each aircraft type

5.8.2 Reverse Thrust Minimisation Policy

Whilst Table 13 indicates that it is theoretically possible to land on a dry runway at Manston Airport with a tailwind of up to 5kts without the use of reverse thrust, it is important to note that this table gives the theoretical distances with no other external factors affecting landing characteristics. If the runway was wet the landing lengths required would be greatly increased and reverse thrust may be necessary. However, if the runway is wet then the preferential runway strategy described in Section 5.4 would mean that the in-to-wind runway was in use which would limit the need for reverse thrust. As a result, Manston Airport could instigate a policy whereby reverse thrust should be kept to a minimum at all times, and only used on a dry runway for safety reasons.

5.9 AFW Data

AFW analysed preferential runway data for day and night flying operations. The data is shown in Table 14 below:

	Day		Night	
Preference	**Population exposed to noise greater than the LOAEL 50 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the SOAEL 63 dB $L_{Aeq,16hr}$**	**Population exposed to noise greater than the LOAEL 40 dB $L_{Aeq,8hr}$**	**Population exposed to noise greater than the SOAEL 55 dB $L_{Aeq,8hr}$**
Normal Operations	100% (34,540)	100% (774)	100% (42,584)	100% (1,020)
Departures on RWY28 and Arrivals on RWY10	20%% (-27,660)	32% (-528)	28% (-30,708)	29%% (-721)
Departures on RWY10 and Arrivals on RWY28	120% (+6,819)	711% (+4727)	110% (+4,182)	743% (+6,561)

Table 14 - Percentage of baseline levels for preferential runway options

The data in Table 14 supports the preferential runway strategy described in Section 5.4. When all departures are on Runway 28, and all landings on Runway 10 the population exposed to noise above the LOAEL is reduced by 72 to 80% and there is also large reduction in the number of properties exposed to noise levels above the SOAEL. When all departures are on Runway 10 and all arrivals are on Runway 28 the population exposed to noise levels above the LOAEL increases by 10 – 20% and the population exposed top noise levels above the SOAEL increase by a factor of more than 7.

5.10 Conclusion

For a preferential runway strategy to be effective, Manston Airport would maximise landings on Runway 10, and take-offs from Runway 28. However, use of this strategy is limited by a range of factors including the movement rate, and by the requirement to use the in to wind runway in wet or contaminated runway conditions.

Through modelling, it has been determined that preferential runway operations would have to cease if the planned movement rate exceeded 5 movements per hour. Beyond this level, conventional runway operations would have to take effect to facilitate a higher movement rate regardless of prevailing weather conditions.

Based purely on meteorological conditions, the tailwind component would be within acceptable safe limits for landings on runway 10, 72.8% of the time. The tailwind component was also assessed as being acceptable safe limits for take-offs from runway 28, 86.06% of the time.

Assuming that the data sets are 'mutually exclusive' (ie a tailwind on one runway will constitute a headwind on the other) it is possible to state that, based purely on meteorological factors, preferential runway operations may be feasible 72.8%, of the time.

A review of the rainfall data for 2016 revealed that the runway was wet (using the definition given in this report), for 1.24% of the time. However from discussions with operational experts, it was determined that this calculation could be too low as rainfall may not be the only cause of reduced runway friction. It was therefore determined that the percentage of time runway friction is reduced is up to 5%.

We do not have the level of meteorological data required to correlate when, during the 72.8% of the time that wind conditions would allow preferential runway operations, the runway was wet. However, by combining this figure with the upper estimate of time when the runways friction may be reduced (5%), which would negate the use of preferential runway operations, it is could be reasonably concluded that preferential runway operations may be feasible 67.8% of the time. Clearly, there are a range of additional factors which may reduce this estimate further and it would not be possible to implement such procedures for more than 5 movements per hour, irrespective of weather conditions.

6 Conclusions

When considering potential noise mitigation measures from an operational perspective, it is important to recognise that, as they may have a bearing on aircraft safety, operators and ultimately aircraft captains will the final say on whether they can be employed. That said, it would be anticipated that the airports intention to employ such measures would be clearly articulated in the relevant aeronautical publications.

It should also be noted that some noise mitigation measures are 'mutually exclusive' – for example it would not be possible to fly steeper approaches to a runway that has been foreshortened by an inset threshold. Equally, some measures may result in an unintended increase in noise, such as increasing the occasions when thrust reverse may be used, increasing the number of missed approaches or introducing changes which require pilots to fly with higher power settings or increased use of flaps.

Turning to the specific noise mitigation measures considered by this study. Having examined the proposition of an inset runway threshold, analysis suggests that the benefits gained will be minimal and localised. The inset distances required to create a significant noise reduction effect would put significant restrictions on the types of aircraft that could be accepted at a reopened Manston Airport if the former runway dimensions were utilised, so it is considered that this option is not a feasible noise mitigation method.

The rationale behind increasing the runway length is that an inset threshold can be added whilst maintaining the LDA. Analysis has shown that the effect of an inset threshold is localised unless the displacement is very large (500-1,000m). In addition to excessive cost, extending the runway at Manston by this length would be a massive engineering project, with associated planning permission, environmental constraints and potential public objection with which to contend; equally, creating an inset threshold that would only have the highly localised benefits previously described. Based on the costs associated with runway extensions projects and the minimal noise benefit of a displaced threshold, it is considered that altering the runway length is not a feasible noise mitigation option.

The steepest approach angle currently permissible is 3.5° in accordance with ICAO PANS-OPS Doc 8168[12]. Whilst theoretically a steeper approach angle will reduce aircraft noise, there are a number of operational issues associated with the introduction of steeper approach profiles which influence this. This may result in the need for aircraft certification or the exclusion of certain aircraft types altogether. Equally the steeper approach angle is unlikely to allow use of poor weather approaches such as ILS CAT II/III operations, may increase the potential requirement for additional pilot training and therefore cost for operators and the capital costs associated with updating ground equipment (if required), safety studies and regulatory approvals.

[12] When the angle has been selected purely for noise abatement. For obstacle clearance purposes, the angle can be higher.

The data from AFW suggests that an increased approach angle would result in some noise reduction; however, as was seen in similar trials, the benefits can be reduced by operators or aircraft captains being unwilling or unable to fly steeper approaches. There is therefore a need to duplicate some infrastructure to accommodate both conventional and steeper approaches. In addition, the data from the 2012 Frankfurt Airport study suggests that the aircraft may be noisier at the final stages of approach as they were completing the approach at a slower speed and hence noise exposure would be extended. Due to the uncertainty over the noise reduction benefits, operational limitations and the cost of duplicating airport infrastructure, it is considered that this option is not a feasible noise mitigation measure.

Undoubtedly the most consistently effective noise mitigation measure is the use of a preferential runway strategy with take-offs from runway 28 and landings on 10 where wind conditions allow. Analysis of historical meteorological data, combined with evidence of when runway friction may be reduced, indicates that a preferential runway strategy could be employed 67.8% of the time. However, having modelled the movement of aircraft on the ground and in the air, it is anticipated that this strategy would only be employed when traffic intensity is less than 5 movements per hour.