Appendix 11.1: Wind Farm Aviation and Lighting Mitigation Report

WPAC
Wind Power Aviation Consultants Ltd

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Wind Farm Aviation Lighting and Mitigation Report for Dunside Wind Farm V2.0

Our Reference: WPAC 016/23
Your Reference: Dunside EIA Technical Appendix

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Reference Documents

A. Civil Aviation Publication (CAP) 764 Civil Aviation Authority (CAA) Policy and Guidance on Wind Turbines Version 6, Feb 2016
B. CAP 764 Version 7 (Draft) issued for comment in June 2020 (to be released shortly)
C. Air Navigation Order (ANO) Article 222
D. CAA Policy Statement: Lighting of Onshore Wind Turbine Generators in the United Kingdom with a maximum blade tip height at or in excess of 150m Above Ground Level dated 01/06/17
E. NatureScot General pre-application and scoping advice for onshore wind farms dated Sep 2020
F. International Civil Aviation Organisation (ICAO) Annex 14 Vol 1 Chapter 6
G. NPF4 Policy 11 para e ii & iv

Scope

1. This report is divided into two parts. Part 1 proposes a lighting design that is compliant with existing and draft (but soon to be ratified) regulations and guidance contained within References A to D and F as discussed with the CAA and the MOD. It explains the rationale behind the lighting design taking into account the requirement to minimise the number of turbines illuminated with aviation obstruction lights whilst maintaining flight safety and provides a detailed assessment of the brilliance of the lighting when viewed from a number of viewpoints provided by the LVIA consultant after consultation with the relevant stakeholders including NatureScot and the Local Planning Authority. Part 2 of the report identifies and explains those mitigation measures that can be utilised to minimise the environmental effect of the lights including an assessment of the historical meteorological data from which to predict the luminous intensity requirements for the lights. The entire report can be considered to fulfil the requirements for an Aviation Lighting Landscape and Visual Impact Mitigation Plan as proposed by NatureScot in their response to a recent Wind Farm Inquiry.

Part 1 Turbine Lighting Layout Design

Introduction

2. WPAC have designed a number of CAA and MOD compliant lighting layouts for wind farms and have also been in constant dialogue with the CAA regarding the proposed change to CAP 764 in terms of aviation lighting requirements. Whilst Reference A is technically the current publication for policy and guidance on this issue, Reference B was released for comment and is already being used by the CAA as the current *de facto* policy. Discussions with the CAA have clarified that the draft regulations will not be changing in terms of the overarching policy but the wording may be slightly amended in the interests of clarity.

Lighting Layout Starting Point and Assumptions

3. The proposed Dunside Wind Farm is located on the western end of the Lammermuir Hills in the Scottish Borders. This location is within MOD Low Flying Area (LFA) 16. At night this area converts to Night Allocated Region (NAR) 2A, an area primarily reserved for fast-jet low flying in the hours of darkness. In addition, this part of the East Coast Borders region is also used as an Operational Training Area (OTA). This provides relatively restriction free airspace for fighter vs fighter-bomber training. In essence, this region is a valuable piece of low flying training airspace to both the MOD and NATO.

Lighting Assessment Overview

4. The Dunside site approximately 50km the south-east of Edinburgh Airport. Designated as Class G (unrestricted) airspace, this area will be used by Coastguard, Air Ambulance, HEMS, Police and Military helicopters, operating at night.

- Accordingly, the site will be assessed as Class G 'en-route' airspace insofar as obstruction lighting is concerned in accordance with the latest (still draft) CAA CAP 764.
- To accommodate MOD/Civilian Night Operator requirements, the site will be assessed for NVG compatible lighting in accordance with MOD published obstruction lighting specifications.
- Where possible, the recommended lighting configuration will be optimised to reduce light impact on the local area. Potential dispensations by the CAA and MOD will also be shown.

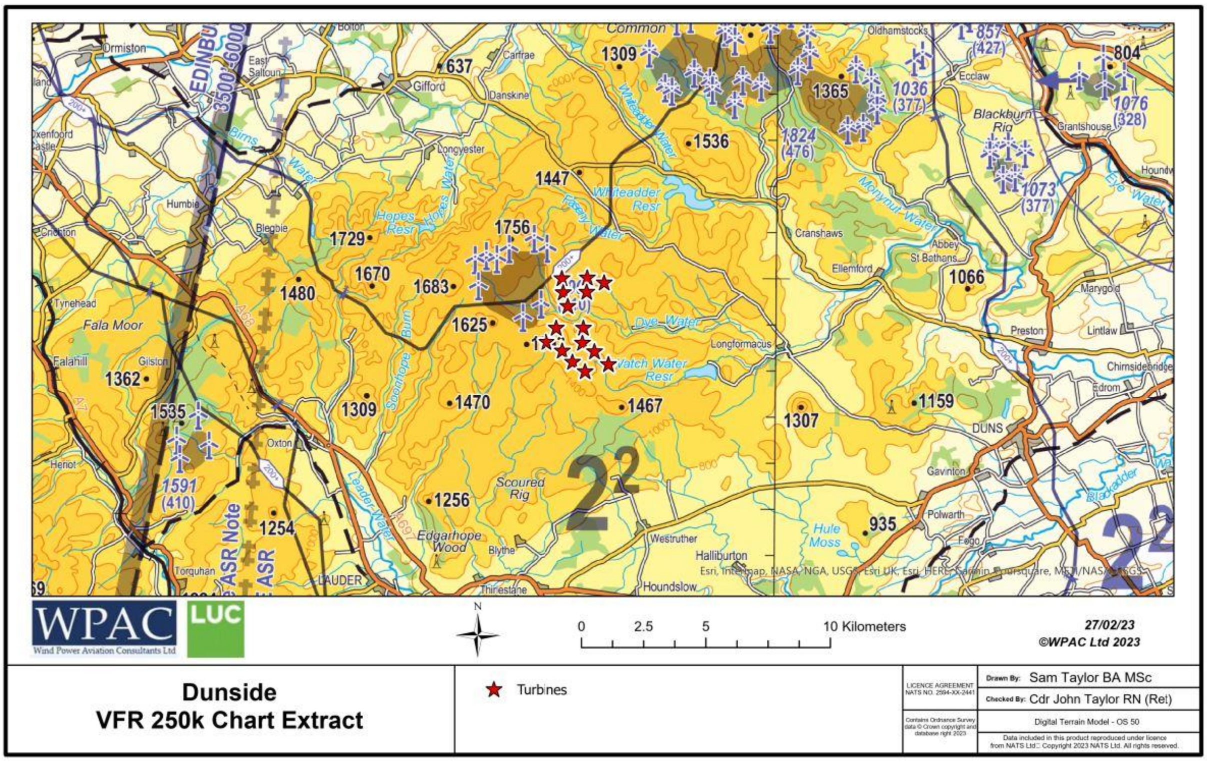

Figure 1 Dunside on an aviation chart

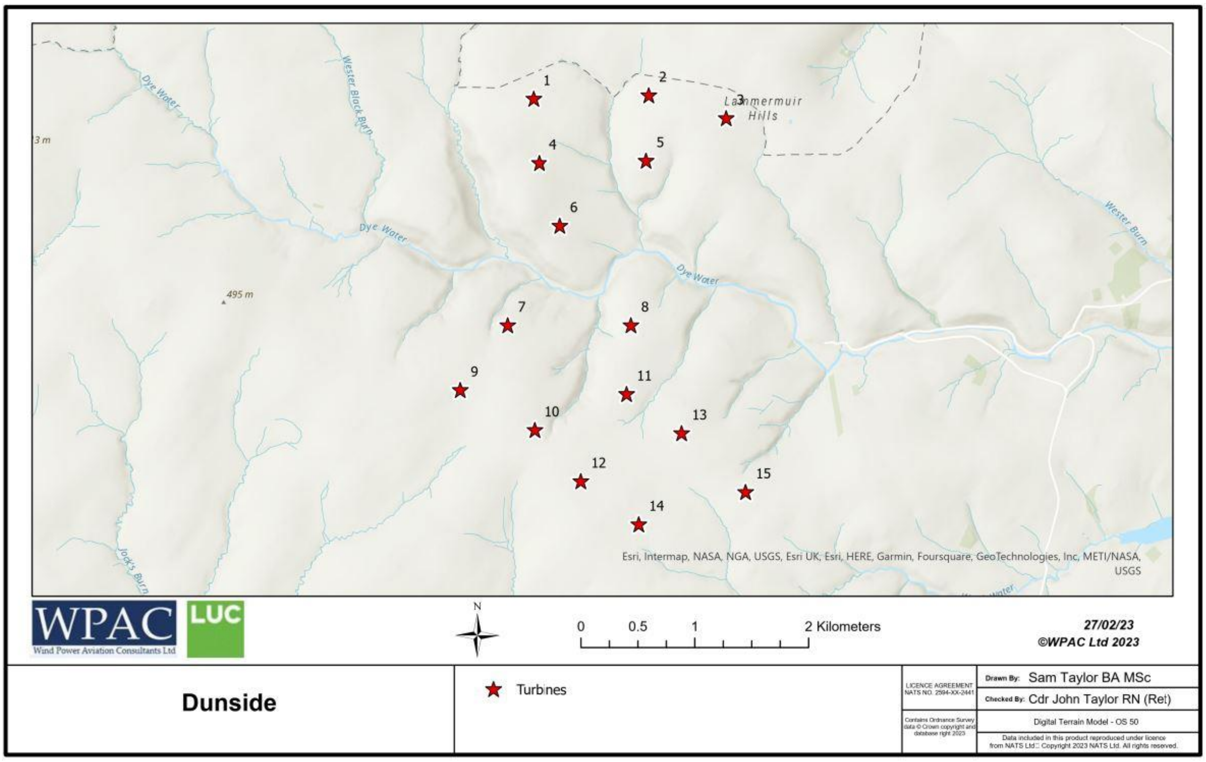

Figure 2 Dunside Wind Farm

CAA-ANO Red 2000/200cd Lighting (In compliance with CAA CAP 764 - Draft)

5. The CAA requires:

- That all 'string-perimeter' turbines be lit unless removing a light will leave a gap of less than 900m total between the remaining lit turbines.

- That any turbine within 200m of a 'string perimeter' be lit unless the distance between adjacent lit turbines is less than 900m total. Note: additional dispensations are sometimes available.

- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines.

- Applying these criteria dictates that 8 turbines of the Dunside site will require ANO visible red lighting.

Note: The site does not sit well with the CAA CAP 764 Draft guidance. The string perimeter assessment results in the turbines concentrated at opposite ends (North & South) of the Dunside Turbine Site.

Turbines with 2000/200cd Lights: T1, T2, T3, T9, T10, T12, T14 and T15

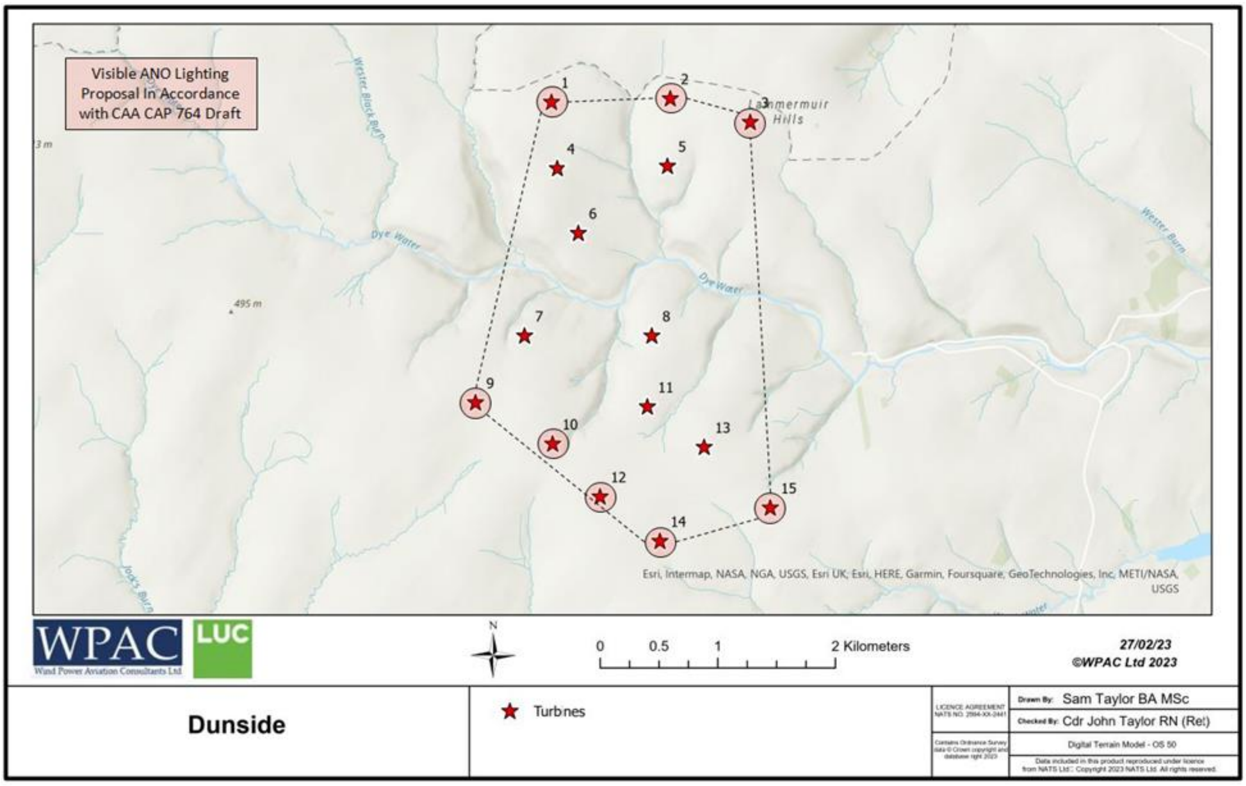

Figure 3 CAA-ANO CAP764 Compliant Lighting Arrangement

CAA-ANO Red 2000/200cd Lighting. (Reduced Lighting using CAA Dispensations)

6. The CAA will accept adjusted lighting proposals particularly where the site is not a good fit with the published CAP 764 assessment criteria and/or the proposal will increase flight safety.

- The layout shown below better represents the turbine site than that of the CAP layout on the previous page.
- Accordingly, WPAC have proposed that lighting be retained on the dominant corner turbines (T1, T3, T9, T14 and T15) and the remaining lights be moved away from these dominant lights to positions that accurately define the site size and perimeter of the site (T6 and T8).

This reduced lighting proposal would require that 7 of the 15 turbines at the Dunside site be fitted with ANO lighting.

Turbines with 2000/200cd Lights: T1, T3, T6, T8, T9, T14 and T15

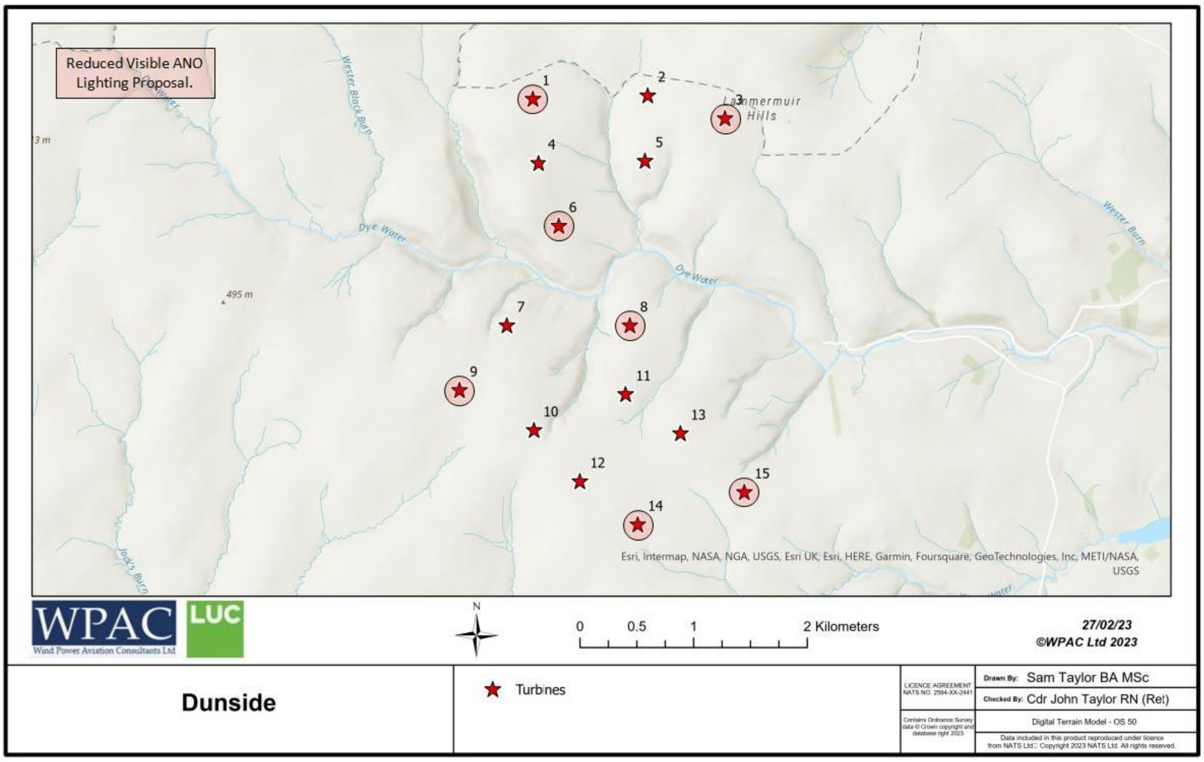

Figure 4 : Dunside Wind Turbine Site - Adjusted Lighting Layout.

MOD Lighting Requirements

7. Early detection is important especially if the aircraft is manoeuvring hard and the air temperature profile causes the turbines to blend into the background. Suitable lighting is necessary for flight safety.

8. MOD IR lights have been developed to be invisible to the public at large but very detectable to aircrew night vision aids. As such the MOD IR lights can have a wide beam width and flash continuously without disturbing the visible environment.

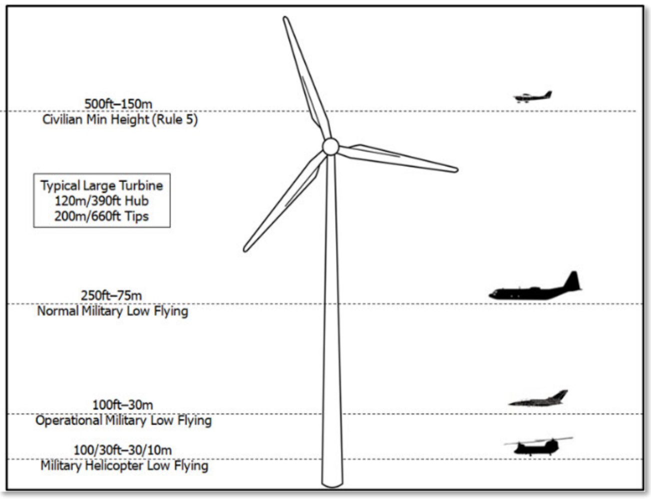

Figure 5 Wind turbine in context with MOD Low Flying

MOD Infra-Red Lighting Layout

9. The MOD requires:

- That all 'compound-perimeter' turbines be lit unless removing a light will leave a gap of less than 500m between the remaining perimeter lit turbines.
- That any dominant turbine, by location or height, be lit. Note: here, the corner and highest turbines are lit.
- That central turbine(s) be lit to provide 'depth perception' to approaching aircraft unless the site meets the MOD small site criteria (Red Circle). Dunside does not meet this criterion and all turbines should carry an IR light.
- Where the IR lighting concentration is high the MOD may approve a reduction in IR lights to help prevent NVG 'gain-down' - an undesirable effect on NVG performance. It is not expected that Dunside will receive this dispensation.

Applying these criteria dictates that all turbines of the Dunside site will require MOD IR lighting. This results in all 15 turbines carrying infra-red lights.

Turbines with Infra-Red Lights: T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T14 and T15.

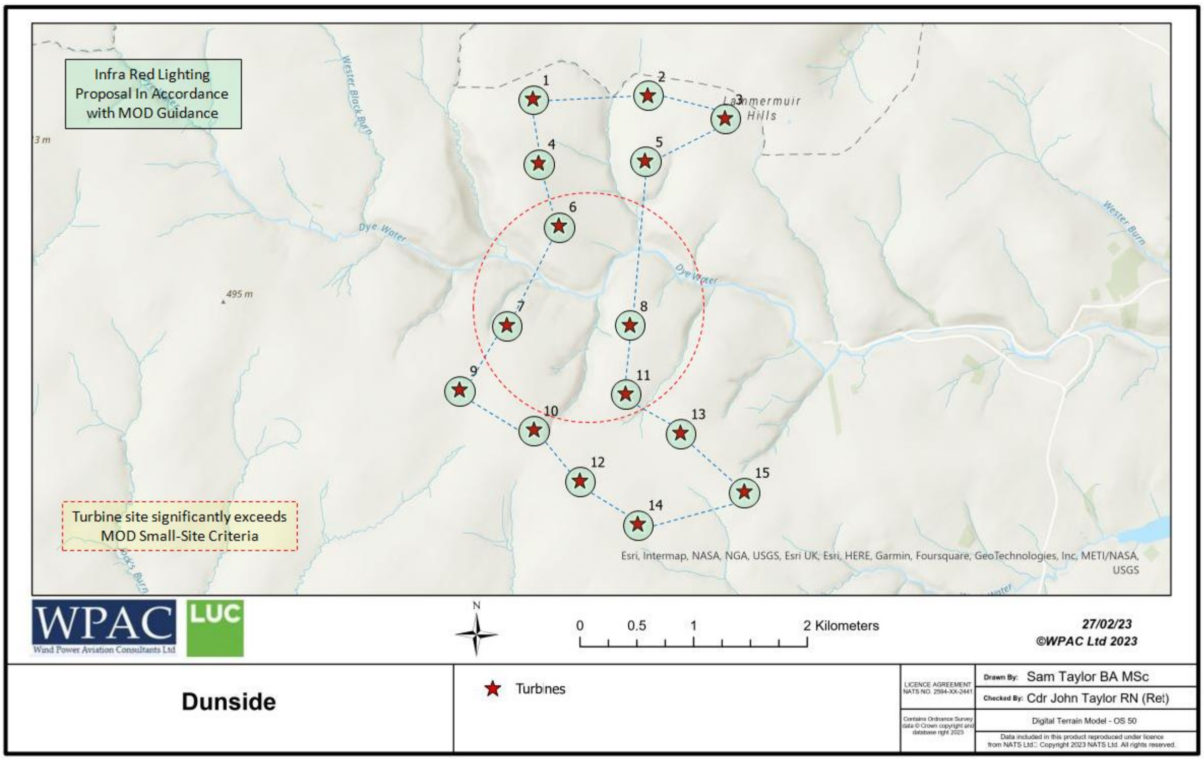

Figure 6 Proposed MOD Infra-Red Lighting Arrangement

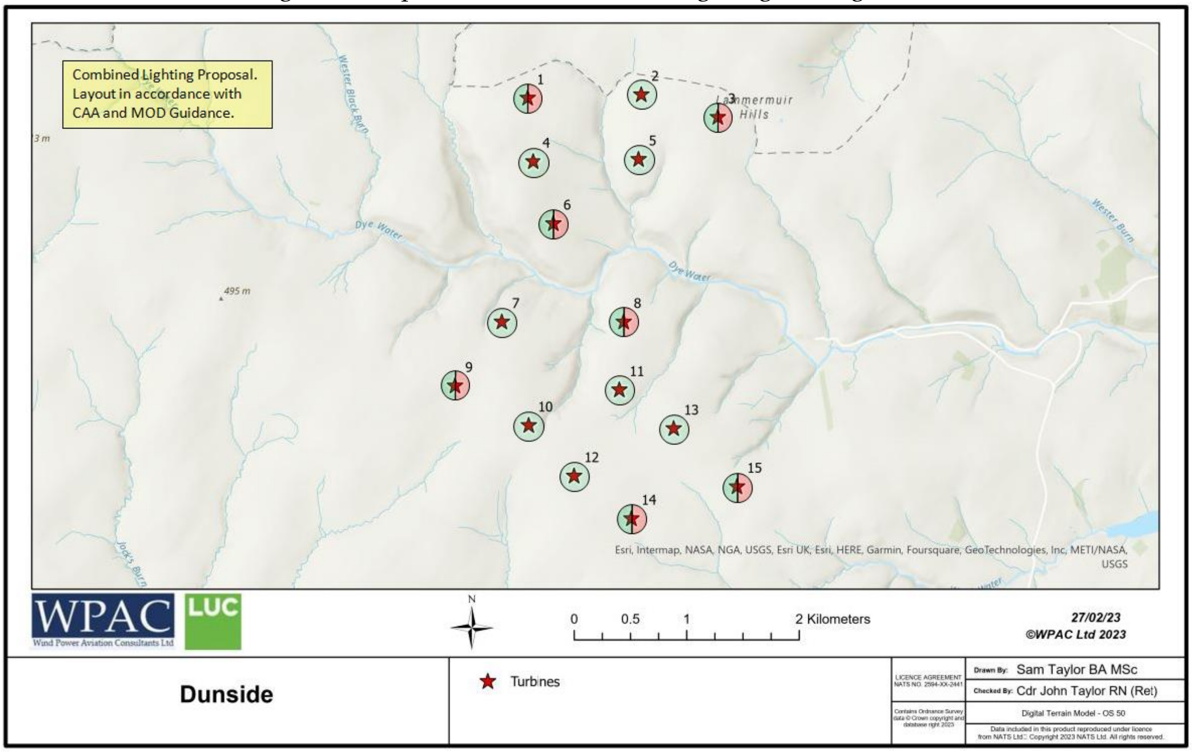

Figure 7 CAA-ANO Visible Red and MOD Infra-Red Lighting Arrangement

Combined CAA Visible Lighting and MOD Infra-Red Lighting

Dunside Turbine & Lighting Table							
Turbine	Easting	Northing	Hub Ht	Tip Ht	Rot Dia	ANO	MOD
1	360176	660152	134m	220m	172m	2000/200cd	600mW/sr
2	361195	660182	134m	220m	172m		600mW/sr
3	361875	659981	134m	220m	172m	2000/200cd	600mW/sr
4	360226	659587	134m	220m	172m		600mW/sr
5	361171	659607	134m	220m	172m		600mW/sr
6	360413	659036	134m	220m	172m	2000/200cd	600mW/sr
7	359947	658162	134m	220m	172m		600mW/sr
8	361038	658162	134m	220m	172m	2000/200cd	600mW/sr
9	359530	657593	134m	220m	172m	2000/200cd	600mW/sr
10	360186	657242	134m	220m	172m		600mW/sr
11	361000	657558	134m	220m	172m		600mW/sr
12	360598	656792	134m	220m	172m		600mW/sr
13	361483	657214	134m	220m	172m		600mW/sr
14	361107	656413	134m	220m	172m	2000/200cd	600mW/sr
15	362045	656697	134m	220m	172m	2000/200cd	600mW/sr

Table 1 Proposed CAA and MOD Lighting Arrangement

ANO Light Specifications

10. The ANO 2000/200cd Lights will conform to the ICAO specification as set out in Annex 14 Table 6-3 as replicated in Table 2 below. The lights will also be controlled such that when the visibility is greater than 5km in all directions from all turbine hubs, the lights will be reduced to 200cd (10% of normal power). This reduction in power will not apply to MOD IR Lights.

ICAO Annex 14 Table 6-3 (excerpt)

Benchmark intensity	Minimum requirements					Recommendations				
	Vertical elevation angle (b)			Vertical beam spread (c)		Vertical elevation angle (b)			Vertical beam spread (c)	
	0°		-1°			0°	-1°	-10°		
	Minimum average intensity (a)	Minimum intensity (a)	Minimum intensity (a)	Minimum beam spread	Intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum intensity (a)	Maximum beam spread	Intensity (a)
2000	2000	1500	750	3°	750	2500	1125	75	N/A	N/A

a) 360° horizontal. All intensities are expressed in Candela. For flashing lights, the intensity is read into effective intensity, as determined in accordance with the Aerodrome Design Manual (Doc 9157), Part 4.
b) Elevation vertical angles are referenced to the horizontal when the light unit is levelled.
c) Beam spread is defined as the angle between the horizontal plane and the directions for which the intensity exceeds that mentioned in the "intensity" column.

Table 2 ICAO Annex 14 Table 6-3 Medium Intensity Lighting Specifications.

11. **Low Intensity Mid Mast Lights** – Mid mast lighting was originally intended to give an attitude/range reference (horizon indication) to pilots flying at night in the days before NVGs. Hub and mid mast lights will give a vertical reference (from which a horizontal reference can be gauged) when fitted to a single vertical structure. In contrast, a single light will not be able to give a vertical or horizontal reference or indication of range and range-rate. However, a series of single hub lights, on a group of structures, will provide a good horizon reference together with range and range-rate clues. Accordingly, the requirement for mid-masts lights is much diminished if not made redundant in the case of multiple vertical structures such as wind farms.

12. All of the current commercially available 32cd (supposedly focused) lights are over-engineered (up to 70cd between -30deg and +40deg to fit a multitude of aviation and marine applications) they induce a disproportionately large environmental impact, often significantly more than the focused hub 2000/200cd lights. WPAC requested that the CAA guidance requirement for 32cd (Type B) mid mast lights be removed for Dunside which they have agreed to as confirmed in their response which is attached at Appendix C.

Table 6-2. Light distribution for low-intensity obstacle lights

	Minimum intensity (a)	Maximum intensity (a)	Vertical beam spread (f)	
			Minimum beam spread	Intensity
Type A	10 cd (b)	N/A	10°	5 cd
Type B	32 cd (b)	N/A	10°	16 cd
Type C	40 cd (b)	400 cd	12° (d)	20 cd
Type D	200 cd (c)	400 cd	N/A (e)	N/A

Note.— This table does not include recommended horizontal beam spreads. 6.2.1.3 requires 360° coverage around an obstacle. Therefore, the number of lights needed to meet this requirement will depend on the horizontal beam spreads of each light as well as the shape of the obstacle. Thus, with narrower beam spreads, more lights will be required.

Table 3 ICAO Annex 14 Table 6-2 Low Intensity Obstacle Lights.

IR Light Specifications

13. The IR lights will conform to the MOD specification as set out in MOD Lighting Guidance and shown below in Table 4.

MOD Specification IR.

IR wavelength – 750 to 900nm.
But ideally concentrated within 800 to 850nm for optimum detection by all military NVG types.

IR intensity – 600mW/sr minimum at peak flash but not above 1200mW/sr.
(Note: Typically a 300mW/sr steady burn LED IR light will generate 600mW/sr at peak flash)
This will generate a 7-8 nm NVG pick-up range - remaining above 5nm as the light ages.

Horizontal Pattern – unrestricted 360 deg.

Vertical Pattern – Minimum flash intensity of 600 mW/sr between +30 deg and -15 deg elevation.
– up to 50% reduction between +25 to +30 deg and -10 to -15 deg is acceptable.
– Maximum intensity of 1200 mW/sr for all angles of elevation.
– Vertical overspill is acceptable.

Flash Pattern – 60 flashes per min at 100-500 ms duration (ideally 250ms)

Synchronisation – all lights to be visually synchronised across a wind farm site

Table 4 MOD Specification for IR Obstacle Lights

Timings

14. The lights (IR and ANO) will be switched on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac; approximately 11 hours per day when averaged over the year.

Assessment of Aviation Lighting and Potential Mitigation Measures Designed into the Lights

15. Having defined a layout of turbines to be fitted with visible lighting, an assessment has been undertaken to calculate the brilliance of the lights when seen from a number of viewpoints. The standard aviation lights to be fitted to the nacelle of the turbines are required to fulfil certain design criteria in terms of brilliance and coverage as per Table 2. They are designated 'medium intensity obstruction lights' and have a **minimum** luminous intensity of 2000 candela[1] at horizontal and slightly above. The LED lights are also required to be able to shine a beam that reduces in intensity above and below the horizontal. One manufacturer of such obstruction lights, CEL, have tested their light, the CEL ACWGAM[2] in a calibration chamber and produced results showing precisely how much the beam reduces in brilliance at any specified elevation angle. The results are provided to every 0.1°. These lights are already fitted in a number of locations around the UK.

[1] Candela is the SI Unit of luminous intensity and refers to the amount of light emitted in a particular direction.

[2] The Technical Specification is at: https://www.aircraftwarninglights.co.uk/datasheets/CEL-MI-ACWGAM - datasheet rev10.pdf

16. Figure 8 demonstrates the reduction in luminous intensity below the horizontal and also above 1° in elevation. The various coloured lines are the candela measured from different angles in the horizontal in order to measure the performance all around the light.

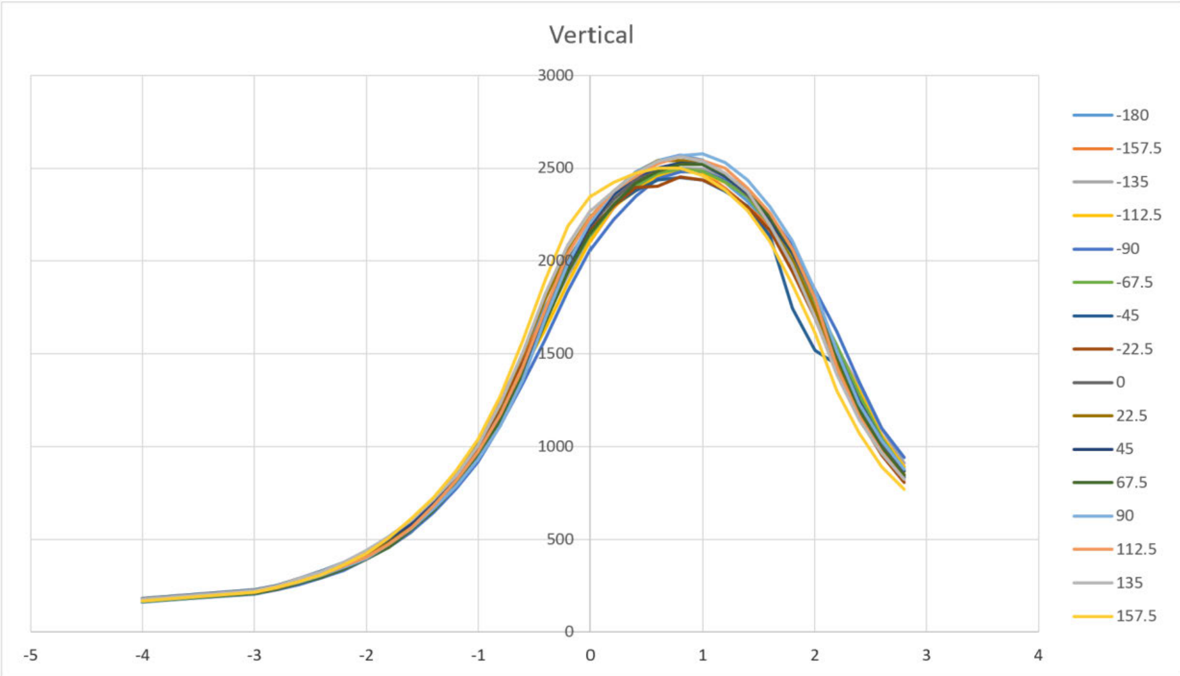

Figure 8 (MI ACWGAM Light Measurement Results)

17. WPAC have utilised their propagation modelling system (Rview) to calculate the precise angle of elevation between the turbine light and a viewpoint assuming a height of eye of 1.5 metres and a turbine hub height of 134 metres. The system utilises a standard atmospheric model and an earth model that uses actual earth curvature between the turbine light and the viewpoint. Ordnance Survey OS50 DTM is used as the terrain model. The calculations have been undertaken for each designated lit turbine against all 24 designated Dunside Wind Farm viewpoints. The locations of the viewpoints are shown in Figure 9 and Table 5. The assessment has been undertaken utilizing the turbine lighting layout shown in Figure 4 and Table 1. It is possible that one or two viewpoint locations may be moved very slightly when the on site photography is completed, but for all practical considerations, the results for each point will remain the same.

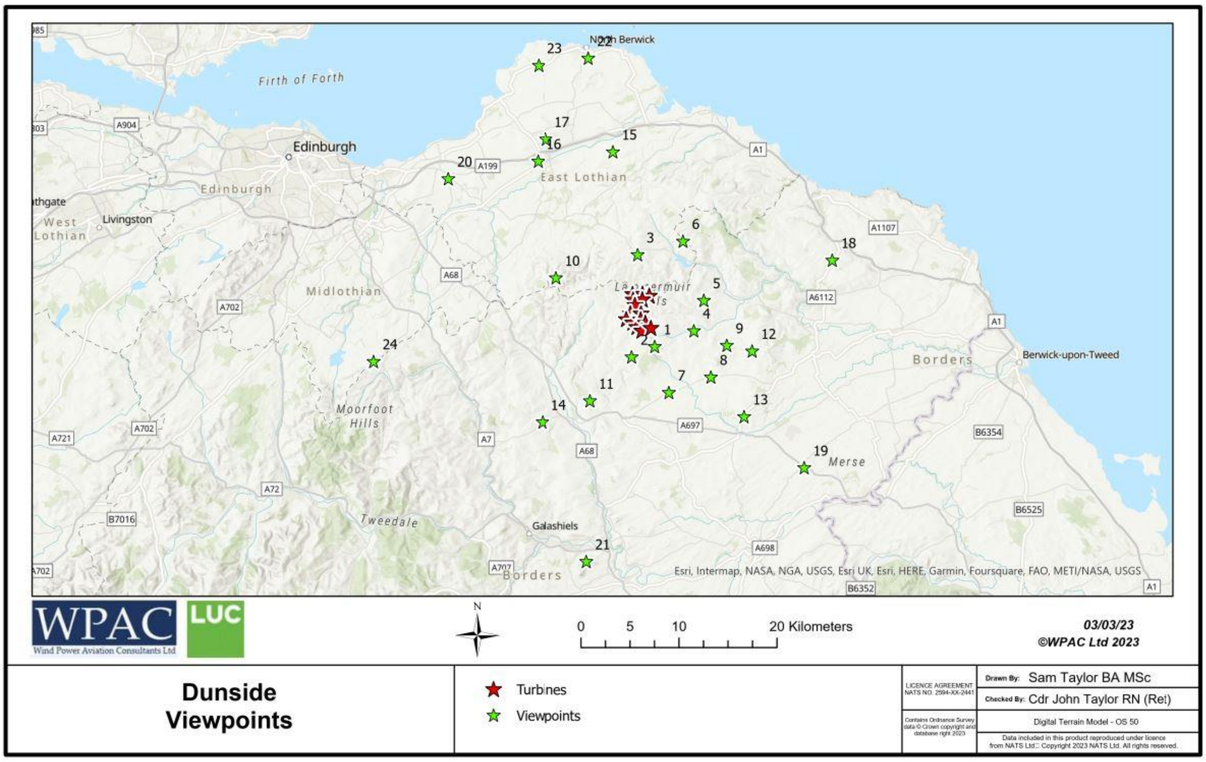

Figure 9 Viewpoint Locations

18. The next stage in the process is to take the candela figures radiated towards a viewpoint and taking into account the distance, calculate the lumens per square metre (also known as Lux) that will be experienced by the human eye at the viewpoint. The figure produced is in micro-lumens per square metre or lumen$^{(10-6)}$/m^{2}) or lux$^{(10-6)}$. These are perfect clear-air figures and therefore worst case results from an LVIA perspective. Figures obtained by this method enable comparisons to be made with commonly understood light sources such as stars or planets. In practice the light intensity at the observation points will be further attenuated by scatter and absorption by airborne dust, droplets and aerosols in the atmosphere. This attenuation is typically in the order of 10 to 20% but can be as high as 75% at the more distant observation ranges.

19. The results for every lit turbine from all of the viewpoints are shown in the results tables in Appendix A to this report. Viewpoints where lights are obstructed by terrain are shaded in green, when the viewpoint is too close to a turbine to get an accurate assessment it is shaded red. **To take into account any limitations within the terrain model we have highlighted in purple any viewpoints where the line of sight is under 10 metres above ground level but above 1.5 metres and should therefore, still be screened by terrain but may be visible within the vicinity of the viewpoint**.

Viewpoint Number	Viewpoint Name	Easting	Northing
1	Twin Law Cairns	362427	654797
2	Nun Rig, Southern Upland Way	360070	653739
3	Minor road near Wanside Rig junction	360685	664167
4	Watch Water Reservoir, Southern Upland Way	366424	656403
5	Minor road near Wrunk Law	367440	659503
6	Spartleton Hill	365316	665541
7	B6456, Westruther	363872	650109
8	B6456 near Bedshiel	368161	651683
9	Dirrington Great Law	369782	654919
10	Lammer Law	352350	661807
11	Edgarhope Wood, Southern Upland Way	355819	649263
12	Minor road near Hen Law	372368	654336
13	A6015 near Greenlaw	371546	647646
14	B6362 above Lauder	350920	647099
15	Traprain Law	358167	674659
16	Park Lane, Haddington	350451	673707
17	Barney Hill, Garleton Hills	351263	675958
18	A6112 near Fawcett Wood	380541	663605
19	A697 near Coldstream	377676	642442
20	B6371, Tranent	341267	671913
21	Eildon North Hill	355443	632869
22	North Berwick Law	355642	684216
23	A198, Dirleton	350517	683483
24	Torfichen Hill	333650	653270

Table 5 Viewpoints

Interpreting the Results

20. The results show that there is a significant decrease in the luminous intensity (candela) of the light emanating towards those viewpoints which are at lower angles of elevation in relation to the turbine hub. However, when considering the perception of the light from a viewpoint in general, the distance between the light and the viewpoint is likely to be the dominant factor and the resultant figure in micro-lux is the most relevant figure to consider. This report provides the results and anticipates that the Landscape and Visual Impact Assessment (LVIA) consultants will be able to put them into the correct context for visualisations in terms of background environmental lighting and atmospheric conditions. Table 6 shows the turbine with the greatest potential perceived luminous intensity expressed in micro-lumens per m^2 (Lux $^{(10\text{-}6)}$) at each viewpoint.

Viewpoint	Brightest Lit Turbine	Distance (km)	microlumens per m^2 (lux$^{10-6}$)	Microlumens at 10%	Obscured
1	8	3.64	52.1	5.2	
2	14	2.87	18.4	1.8	
3	8	6.02	27.1	2.7	
4	15	4.39	10.1	1.0	
5	8	6.54	11.3	1.1	
6	3	6.54	25.4	2.5	
7	15	6.84	4.9	0.5	
8	15	7.91	5.3	0.5	
9	15	7.94	13.0	1.3	
10	6	8.53	27.3	2.7	
11	15	9.70	8.0	0.8	
12	8	11.96	5.8	0.6	
13	15	13.12	3.7	0.4	
14	14	13.80	4.0	0.4	
15	1	14.65	3.0	0.3	
16					X
17	1	18.15	2.3	0.2	
18	3	19.02	2.3	0.2	
19	15	21.16	1.5	0.2	
20					X
21	14	24.22	2.7	0.3	
22	6	25.63	1.7	0.2	
23	1	25.25	1.2	0.1	
24	9	26.24	2.5	0.2	

Table 6 Brightest Turbine Hub Light from each Viewpoint (measured in micro-lumens)

21. In order to place the values in microlumens per m² (lux$^{10-6}$) in context, Table 7 provides some examples of approximate values placed on a number of environmental comparators, however these are just an illustration to place the results in a real world environment. The actual perceived brightness will depend upon a number of factors including bulb manufacturer, bulb type, specific construction (single/multiple colour LEDs etc) atmospheric conditions, absorption spectrum, individual eye characteristics and capabilities.

Comparison Object	Approximate Illuminance (micro-lumens per m²)
Car Halogen main beam approaching 1km	Up to 1,000,000 (can vary significantly between cars)
International Space Station (400km up)	1000 (depends upon relative position of sun)
Car Brake Light at 0.5km	400
Car Brake Light at 0.7km	200
Car Brake Light at 1.0km	100
Car Brake Light at 2.0km	25
Car Brake Light at 5.0km	4
Car Brake Light at 10km	1
Front Cycle Light at 0.5km	140 (Modern high power white LED)
Front Cycle Light at 0.7km	70
Front Cycle Light at 1.0km	35
Front Cycle Light at 2km	9
Front Cycle Light at 5km	2
White LED Street Light at 0.5km	500 (Viewed from the horizontal)
White LED Street Light at 0.7km	250
White LED Street Light at 1.0km	120
White LED Street Light at 2.0km	30
White LED Street Light at 5.0km	8
Sodium Street Light at 0.5km	300 (Viewed from the horizontal)
Sodium Street Light at 0.7km	150
Sodium Street Light at 1.0km	75
Sodium Street Light at 2.0km	20
Sodium Street Light at 5.0km	5
Brightest Star in the Sky (Sirius)	13
Airliner flying at 30,000ft)	Nav Lights 0.4 to 5; anti-collision lights 2 to 20
Typical bright star (e.g. Orion)	0.5 to 2.0
Faintest light visible from street lit area	0.4
Visible limit for fully dark-adapted eyes	0.02

Table 7 Comparisons of approximate micro-lumens values

22. If there is a requirement to consider the brightest turbine in terms of emitted candela rather than micro-lumens, Table 8 provides data on which turbine emits the most candela towards each viewpoint but takes no account of the distance between light and viewpoint.

Viewpoint	Brightest Lit Turbine	Distance (km)	Candela	Candela at 10%	Obscured
1	6	4.69	757	76	
2	1	6.41	448	45	
3	15	7.59	1087	109	
4	14	5.32	208	21	
5	8	6.54	484	48	
6	8	8.53	1582	158	
7	9	8.65	274	27	
8	1	11.64	530	53	
9	8	9.33	1087	109	
10	8	9.42	2084	208	
11	3	12.31	902	90	
12	8	11.96	822	82	
13	8	14.87	822	82	
14	6	15.25	902	90	
15	14	18.48	822	82	
16					X
17	3	19.18	822	82	
18	6	20.64	902	90	
19	3	23.61	757	76	
20					X
21	8	25.90	1721	172	
22	6	25.63	1087	109	
23	3	26.10	822	82	
24	6	27.38	1852	185	

Table 8 Brightest Turbine Hub Light measured in Candela emitted towards a viewpoint

Part 2 Mitigation

Intensity Reduction (ANO Lighting: 2000cd down to 200cd)

23. The lights (IR and visible red lights) will be switched on between Evening Civil Twilight and Morning Civil Twilight in accordance with the UK Almanac; approximately 11 hours per day averaged over the year.

24. The primary mitigation consideration in addition to the already described reduction in brilliance due to elevation angle, is taken from Reference D which states:

> '*If the horizontal meteorological visibility in all directions from every wind turbine generator in a group is more than 5 km, the intensity for the light positioned as close as practicable to the top of the fixed structure required to be fitted to any generator in the windfarm and displayed may be reduced to not less than 10% of the minimum peak intensity specified for a light of this type*'.

25. It is therefore possible to take advantage of the CAA SARG Policy Statement dated 01/06/2017 and incorporate the option to reduce the hub height lighting to not less than 10% of the minimum peak intensity specified for the installation in good weather. In essence, reducing the 2000cd obstruction lights to 200cd in meteorological visibilities greater than 5km. Note: This concession is not applicable to MOD specification IR lighting, which is covered separately.

26. To assess historical visibility in this central area the closest meteorological stations that report long-term visibility and cloud statistics will be referenced. The closest such met-stations are located at Newcastle and Edinburgh Airports. The visibility, at these airports, will not be identical to that at the Dunside site, but it will be similar due to the close geographical locations with the two airports effectively sandwiching the turbine site. Below are two tables of the visibilities at Edinburgh and Newcastle airports. The tables report a series of monthly visibilities over the year and averaged over a 20-year period.

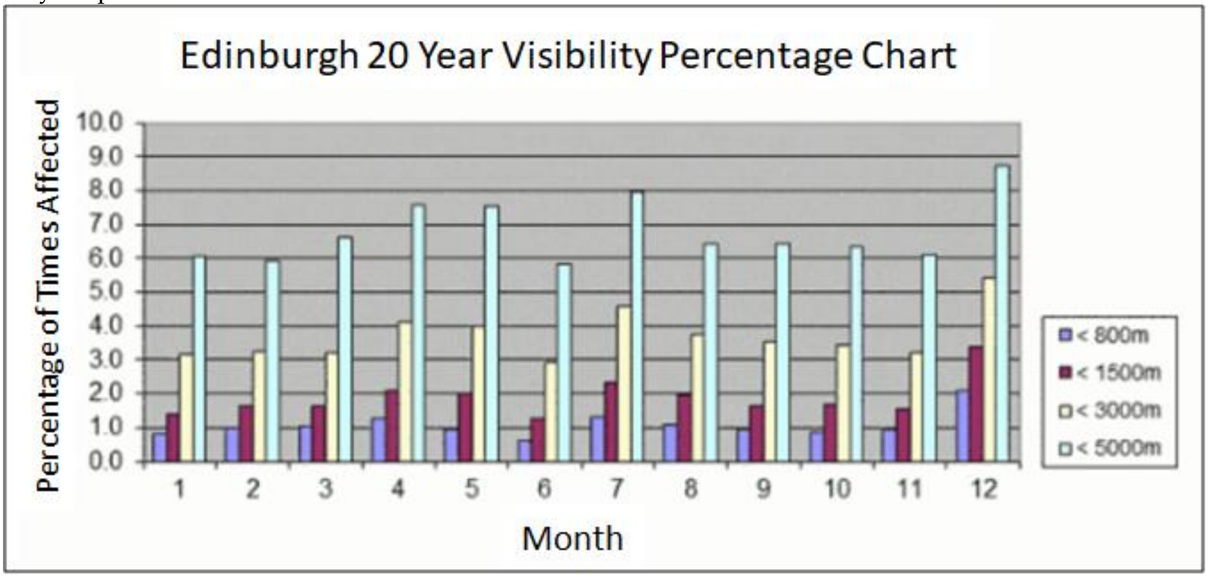

Table 9 Edinburgh Visibility Table

27. This Met Office table shows that the Edinburgh visibility is below 5km for an average of 7% of the time. This suggests that the lights will be at **2000cd for 7% of the time and 200cd for 93% of the time.**

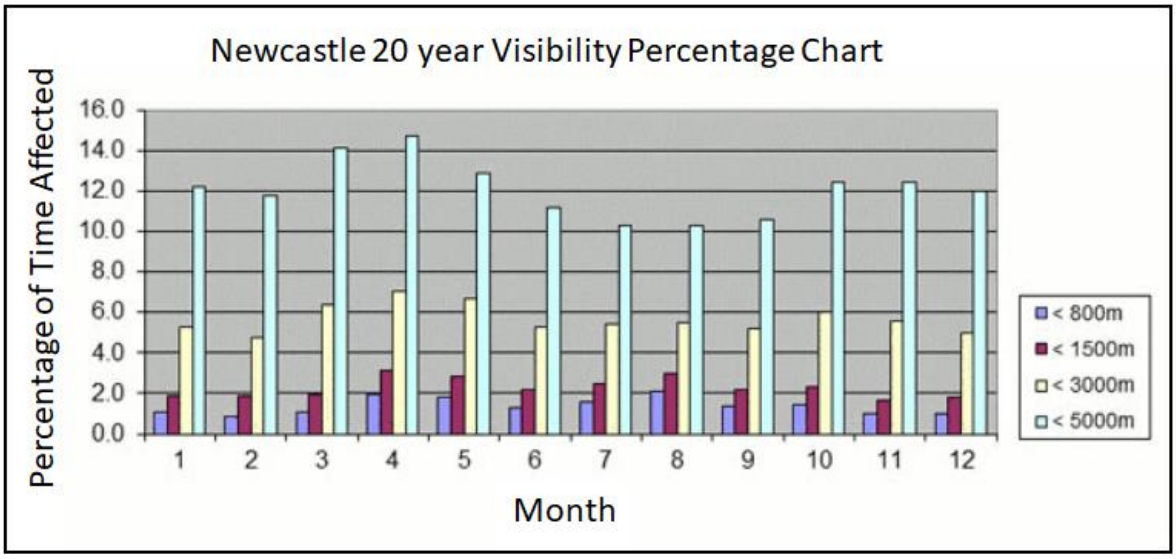

Table 10 : Visibility Table for Newcastle Airport (Light Blue is 5km Indicator)

28. This Newcastle Met Office table shows us that the visibility is below 5km for an average of 12% of the time. This suggests that the lights will be at 2000cd for 12% of the time and 200cd for 88% of the time.

29. With Edinburgh showing 7% vs 93% and Newcastle showing 12% vs 88% a conservative average (rounded to the nearest 10%) will be 10% vs 90%. The lights at Dunside would emit at 2000cd for 10% of the time and 200cd for 90% of the time.

30. Whilst Edinburgh and Newcastle Airports are not Dunside, met visibility improves with height since the concentration of particles (dust, haze) and liquid droplets (water, aerosols) reduces with height and the air also becomes thinner. It could be argued that the Dunside site visibility would be better than that at Edinburgh or Newcastle. In addition, cloud will play its part in the observability of the obstruction lights at Dunside. This will now be investigated.

Obstruction Light Weather Obscuration.

31. On occasion, the visibility in the area of Dunside will reduce significantly due to the presence of cloud on the hills. If the Dunside turbines are in cloud, then the obstruction lights will not be seen. The turbines will carry the 2000/200cd lights on the generator hub. The average height at the base of these turbines is around 450m (1500ft) amsl and the hub heights will be around 135m (440ft) above ground level (agl). Summing the two equates to the lights at around 580m which is 1900ft amsl.

Note: In aviation all heights are given and used in feet.

32. It is now possible to compare these two heights: turbine base 1500ft amsl and turbine hub 1900ft

amsl with the actual cloud bases recorded by the Met Office, at Edinburgh and Newcastle airports, over a 20 year period, shown below in Tables 11 and 12.

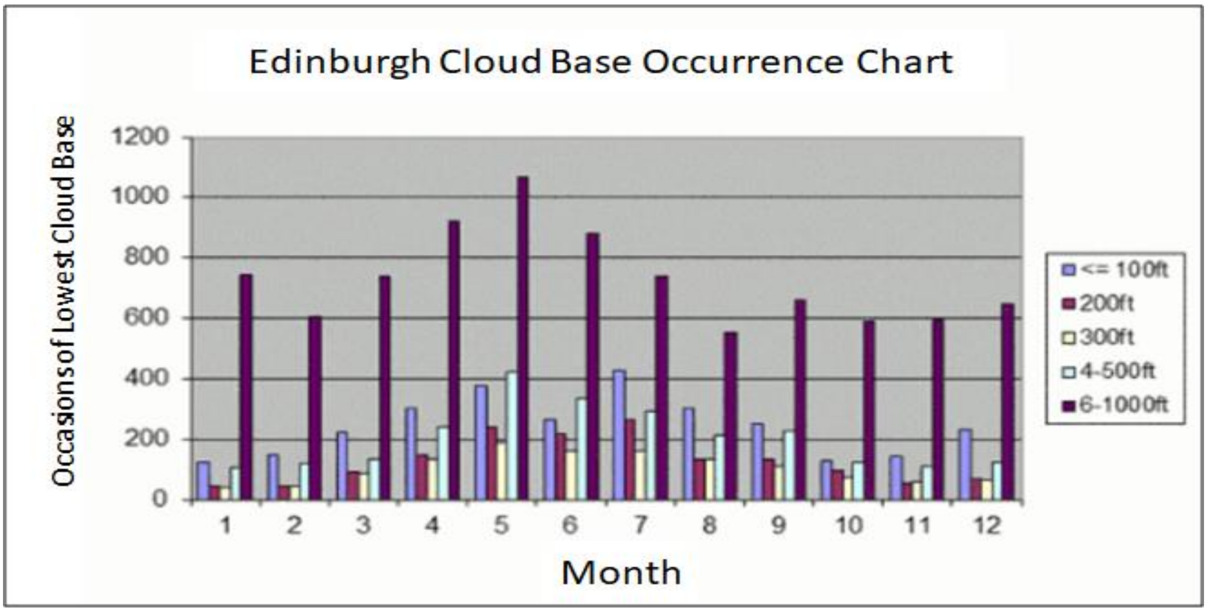

Table 11 Edinburgh 20 Year Average Cloud Base Table.

33. At Edinburgh, the dark maroon columns (600-1000ft) indicate that, on around 700 occasions a month, the cloud-base will be below the turbine base heights (1500ft). Moreover, the visible red obstruction lights, at 1900ft will be completely obscured and not seen.

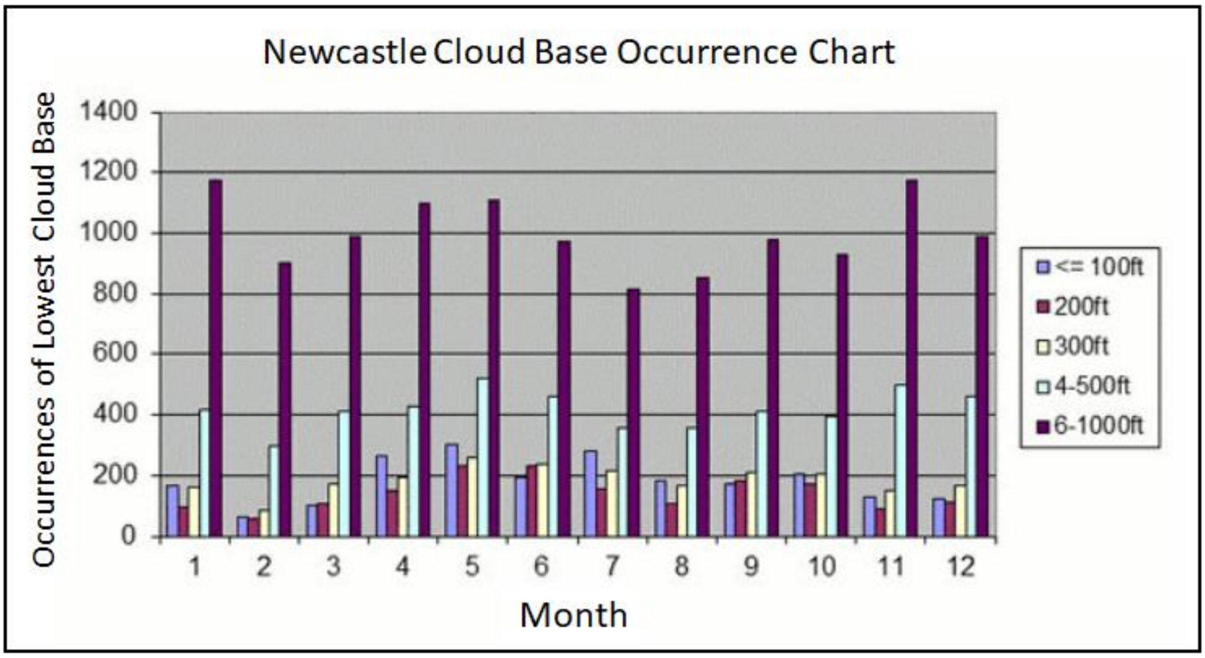

Table 12 Newcastle Airport

34. At Newcastle, the dark maroon columns (600-1000ft) indicate that, on around 1000 occasions a month, the cloud-base will be below the turbine base heights (1500ft). The visible red obstruction lights, at 1900ft will be completely obscured and not be seen.

35. With the Edinburgh Met Office predicting cloud obscuring the turbine lights 700 times a month and Newcastle Met Office predicting 1000 times a month, it is clear that for much of the time the turbine obstruction lights at Dunside will be completely obscured by cloud.

36. Again, whilst Edinburgh and Newcastle Airports are not Dunside, orographic uplift dictates that cloud-bases reduce in the region of hills. It could be argued that at Dunside the cloud-base would, on the whole be lower than at Edinburgh and Newcastle thus providing a greater degree of obstruction light obscuration.

Weather Obscuration Conclusion

37. It is most important not to try and combine the two different observations, visibility and cloud-base, into a single statement. Informal advice direct from Met Office and Airport forecasters indicates the information, gathered for Dunside, should be presented as follows:

Meteorological observations suggest that the turbine hubs will be obscured on several hundred occasions a month by cloud.

When not obscured by cloud, the visibility in the area of the turbines can be expected to exceed 5km for around 90% of the time.

Note 1: There should be no attempt to combine the statistical data in any other way.

Note 2: Adjusting these figures for the dawn to dusk period when the lights will be on (averaging just below 11 hours per day over the full year) will suggest that the lights will be obscured by cloud at night on 350-500 occasions a month. Conversely, the percentage of time that the met visibility will be above 5km will remain unchanged at 90%.

Note 3: Cloud base is recorded in occurrences. An occurrence can be caused by cumulus passing through with each cloud causing an occurrence of minutes to hours. Conversely a stratus cloud (horizon to horizon sheet cloud) can cause one occurrence that can last all day or even longer. Data on cloud presence, at given heights and measured in time (hours/minutes) as opposed to occasions, appears not to be available from Met Offices.

Light Intensity Summary

The weather will impact the observable lighting in several ways, as follows:

- The CAA has approved a reduction in light intensity (2000cd to 200cd) in visibilities above 5km.

- Met Office records suggest that 200cd will be possible at Dunside for around 90% of the time taken as a conservative estimate of when the met visibility is in excess of 5km.

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- Met Office records suggest that cloud will obscure the lights around 700-1000 times a month.

Conclusion/Notes

38. At Table 1 and Figure 7, WPAC have produced an Obstruction Lighting Proposal which has all 15 turbines fitted with Infra-Red lights and 7 dominant, by position, turbines fitted with ANO Visible Red lights. At Tables 2 and 4 the specifications of the lights proposed are set out.

39. The report also outlines the impact of weather on the obstruction lighting, with cloud obscuring the lights completely or good visibility allowing a reduction in the lighting intensity by 90%.

40. WPAC have consulted with the CAA and MOD. CAA approval has been granted and the approval letter is at Appendix C to this report.

Technical Mitigation

41. One other form of potential mitigation commonly discussed is the installation of an Aircraft Detection Lighting System (ADLS). There are two possible methods of detecting an aircraft approaching a wind farm that will automatically turn on the aviation obstruction lights, firstly through the use of a suitable primary surveillance radar (PSR) or secondly, the use of aircraft installed Electronic Conspicuity (EC) equipment with a suitable receiver at the wind farm. There are some significant technical and regulatory issues to be overcome before any such system can be installed and operated in the UK.

42. In the case of PSR, this is already in use at wind farms in Europe; as an example the Terma Scanter 5002 radar is installed at a number of sites as shown in Figure 10. The main regulatory constraint is that although such systems are in use in Europe, in the UK, where airspace tends to be shared to a much greater extent between users, the CAA have yet to mandate the performance parameters that such a system must be capable of fulfilling. For example, the coverage requirement will need to be defined in terms of maximum range of detection and activation (which may vary depending upon the speed of the aircraft), base of cover (above ground level) and almost certainly a maximum height coverage to avoid unnecessary activations, which a PSR on its own cannot ascertain. An initial set of draft requirements was promulgated in 2018 but these were for discussion with aviation stakeholders and the wind industry and it cannot be assumed that these are going to be the final criteria. Even if the standards are defined, it may be that any single radar will not be capable of delivering the required coverage where, for example, a wind farm is located on a hill and aircraft may approach below the wind farm from any direction. It may then become necessary to install multiple radars in order to achieve the required coverage at low level. This in itself may lead to limitations due to mutual interference in what is already a crowded part of the electro-magnetic spectrum, (although the Terma radar does have some anti-interference capabilities) but the additional radars may affect other systems working in the same frequency band. There would also be additional planning issues to consider, such as the visual impact of additional aerials, and rotating arrays. Technical constraints also mean that it will be necessary to position the radars some distance outside the windfarm as shown in the example below in order to avoid turbines screening the radar and to provide the required height coverage.

Figure 10 Terma 5002 Radar at a Wind Farm in Germany

43. The one major advantage of PSR is that it will detect any aircraft, both those transponding and those that are not, known as non-co-operative targets. Depending upon how the regulatory process moves forwards, this may have a major effect on which systems to use for ADLS. In response to a recent planning inquiry paper the CAA responded stating in a letter dated 21 April 2021: *For the UK, there are some challenges to be resolved. The cost/benefit of the use of primary surveillance radar for the active detection of aircraft, spectrum availability, incentive pricing cost and geographical separation required before frequencies can be re-used potentially makes this a less than optimal solution.*

44. The alternate system is one based upon a reliance on aircraft carried Electronic Conspicuity (EC) transponders. Currently light aircraft flying clear of regulated airspace in the UK below 10,000ft are not required to carry a transponder (one example being Secondary Surveillance Radar or SSR). Most aircraft do, but not all. The CAA has been encouraging fitment by all aircraft and hope to have a regulatory system in place within the next few years requiring all flying machines to be fitted. Unfortunately this is not a simple process. This issue has been running for at least 20 years so far, however some limited progress is now being made. In the same response to a recent planning inquiry paper the CAA stated: '*At the same time, the lack of interoperability between the wide variety of electronic conspicuity devices currently available may require careful consideration of the specification of any passive system receivers and how they are deemed compliant to be deployed and operated.* ' The letter goes on to state: '*We concur that not every situation may require ADLS to be fitted and operated; Article 222 or 223 requirements of the Air Navigation Order will remain, and the CAA may agree a specific solution under Section 7 of Article 222 and Section 11 of Article 223. However, ADLS could potentially provide an acceptable means of compliance that could provide greater certainty for developers when developing planning proposals on CAA acceptance and assist with discussions with communities during planning consultation.*' What this letter is saying is that ADSL using EC is technically feasible but that until the regulatory actions concerning the mandatory carriage of a compatible EC system have been completed and signed into law, and the coverage requirements agreed, nothing can be done unless a planning condition to require the retrospective installation of a system is considered appropriate. The length of time that this is likely to take is difficult to estimate, however, realistically it is likely to be within a two to five year timeframe as it is a small part of a much wider airspace modernisation programme currently under way. Additionally, the CAA also issued a Guidance Notice dated 26/10/21 entitled: '*Electronic continuity specifications: enabling interoperability between airspace users*'. This announced the establishment of a task force to jointly develop electronic conspicuity specifications to enable interoperability between airspace users. It goes on to state: '*The adoption of EC specifications will not be mandated UK wide. Users of other systems can continue to benefit from the functionality that those products offer*'. This does not mean that an EC triggered ADLS system will not be feasible, but the regulatory challenges mentioned above may take longer to resolve.

45. What is clear is that once the carriage of compatible transponders is mandated and all aircraft fitted with them, this is likely to be a realistic way of triggering an ADLS system. Such systems are passive at the wind farm and will not, therefore cause any interference. As shown in Figure 11 they require unobtrusive small aerials, approximately 1.2 metres long that are very reliable and relatively inexpensive to install and operate.

Figure 11 ADSB/SSR Passive Aerial

46. Bearing the above in mind, it would be prudent to ensure that lighting installed on the turbines is compatible with any future EC triggered ADSL system, so that when the regulatory process and aircraft equipage has been completed, it will be a relatively cheap and simple exercise to retro-fit such a system. Alternately, the ADSB/SSR aerials and system could be installed when the wind farm is constructed, ready for activation when required. It may therefore be suitable for use as the basis of a planning condition requiring the activation of the system once the regulatory and equipage hurdles have been overcome.

47. An ADSL system may not be suitable for every location, depending upon the nature of aviation operations at night in the area around the wind farm and the activation criteria that are finally mandated by the CAA. If located close to the approach for a major airport for example, the lights might be required to be turning on and off continuously, however, in a location like Dunside, with limited night low level civilian traffic, the lights will rarely be activated. The EC activated ADLS system will be able to differentiate between civil traffic and SAR/HEMS/military traffic using NVD and not therefore activate when these types of aviation operations are taking place within the activation zone for the system. The infra-red lights that these types of operations rely on will always be on at night, but of course are invisible to the naked eye and will have no effect on the visual impact of the development.

Comment

48. In recent months various briefing documents have been in circulation suggesting that visible obstruction lights are not required in the current aviation environment. The CAA have briefed WPAC that they do not support this position and would consider prosecuting organisations that do not follow the existing guidance and regulations. However, change will come; this will be led by the CAA and be centred on the new draft CAP 764 (as adhered to in this report) and the future development of ADLS.

49. From the direct experience of WPAC staff who have over 40 years of day/night low flying over land and sea both with and without NVG/Ds, the inclusion of adequate visible red lighting is important to cater for both routine operations and the inevitable unplanned outcome. Pilots uncertain of their location together with emergency situations and system failures of critical night low flying equipment are circumstances that require a degree of visible obstruction lighting on large wind turbines.

50. In addition, future green energy aircraft (hydrogen/electric and battery powered) will fly considerably lower and slower than current aircraft and will be significantly limited in track variation by much shorter ranges. Good visible obstruction lighting will become more, not less important in this low direct flight environment.

51. Finally, an aircraft colliding with a wind turbine is thankfully an extremely rare event but one with enormous potential consequences. A standard risk assessment as part of an aviation safety case would conclude that even a very low probability of a significant dangerous event is still unacceptable and must be mitigated, in this case by the fitting of visible obstruction lights.

Conclusion

52. This report has assessed the requirements for both visible, CAA approved aviation lighting and MOD approved Infra-Red lighting for the Dunside Wind Farm. The resulting layout is set out in Figures 4 and 6 and makes use of both CAA/ANO medium intensity Red lights and MOD IR lights. The proposed layouts were sent to the CAA and MOD DIO for approval. CAA approval has been obtained as shown in Appendix C.

53. The report also provides the brilliance of lights that will be visible taking into account the elevation angle between the turbine hub obstruction light and the viewpoints and the distance between each turbine and each viewpoint. The report shows that for up to 90% of the time, the lights will only be required to operate at 10% luminous intensity, which will significantly reduce obstruction light effects in the area. Further interpretation of these results can be undertaken by a Landscape and Visual Impact Assessment expert.

54. The report then identifies additional mitigation options that, should the regulatory process allow, enable the visible medium intensity turbine lights to be switched off for the vast majority of the time and activated only on those rare occasions in this location when an aircraft activates the system. A suitably worded planning condition may enable the future lighting effects to be mitigated to the extent of becoming almost non-existent.

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Authors

Cdr John Taylor RN (Ret) – after a career in the Royal Navy specialising in Air Traffic Control (ATC), Airspace Management and Air Defence which culminated in leading both the ATC and Fighter Control Specialisations, John worked for Lockheed Martin UK for three years as a Principal Consultant and Business Area Manager responsible for Air Traffic Management Consultancy, including the provision of advice to wind farm developers. In 2008 he founded WPAC Ltd and since then he and his team have provided aviation advice in relation to over 3000 wind farm and wind turbine sites, given evidence at a number of planning inquiries and enabled many sites to overcome aviation objections where it was feasible to do so. He and his team have also provided advice to a number of Local Planning Authorities, Renewable UK and the Aviation Fund Management Board, including organising workshops and the provision of guidance documents. John also advises planners and developers in relation to physical and technical safeguarding of non-wind farm developments in the vicinity of aviation facilities.

Sqn Ldr Mike Hale RAF (Rtd) has over 45 years, piloting, instructing and examining experience on numerous military fast jet aircraft through to a range of civilian and military general aviation training aircraft and gliders. He has held many posts including Flying Instructor, Training Officer, Flight Commander, Squadron Commander and Principal Tornado AD Force Examiner. He has amassed over 10,000 flying hours of experience when operating at many locations around the world. In parallel to his flying duties, Mike held the post of Officer Commanding the MOD Low Flying Operations Squadron (OC LFOS). In this post he was both Low Level Airspace Manager for the MOD & Wind-Farm Subject Matter Expert for the Defence Infrastructure Organization (DIO). During that period, he assessed over 14,000 wind-farm pre-applications and 2000 full applications against low flying, weapons range, specialist airspace, local community and aerodrome safeguarding criteria. Mike also instigated two Qinetiq ground based Infra Red obstruction lighting trials. These were followed by instigating and managing the MOD Infra Red/Low Intensity (Henlow) flight trials and the CAA/MOD/Trinity-House/RUK off-shore IR/Morse (North Hoyle) flight trials. In conjunction, Mike organised numerous and various supporting trials including night vision equipment compatibility and detailed lighting beam overspill analysis (where light is emitted outside the required specification envelope). In 2012, he was awarded an MBE for generating a proactive and mutually successful working relationship between the Wind Power Industry and the MOD Air Staff.

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Appendix A Lighting Results Tables

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	5.81	-1.3	756.5	75.7	22.4	2.2	X
3	5.21	-1.3	756.5	75.7	27.8	2.8	
6	4.69	-1.3	756.5	75.7	34.3	3.4	
8	3.64	-1.4	690.6	69.1	52.1	5.2	
9	4.03	-2.2	356.7	35.7	22.0	2.2	
14	2.09	-3.6	189.8	19.0	43.6	4.4	
15	1.94	-3.2	207.8	20.8	55.3	5.5	

Viewpoint 1 Twin Law Cairns

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	6.41	-1.9	448.4	44.8	10.9	1.1	
3	6.50	-1.7	529.8	53.0	12.5	1.3	X
6	5.31	-2.1	384.9	38.5	13.7	1.4	
8	4.53	-2.2	356.7	35.7	17.4	1.7	
9	3.89	-3.5	194.3	19.4	12.8	1.3	
14	2.87	-4.3	151.7	15.2	18.4	1.8	
15	3.56	-3.1	212.3	21.2	16.8	1.7	

Viewpoint 2 Nun Rig, Southern Upland Way

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	4.05	-2.0	413.2	41.3	25.2	2.5	
3	4.35	-1.8	483.7	48.4	25.5	2.6	
6	5.14	-1.4	690.6	69.1	26.2	2.6	
8	6.02	-1.0	982.0	98.2	27.1	2.7	
9	6.68	-1.4	690.6	69.1	15.5	1.5	
14	7.77	-1.1	902.2	90.2	15.0	1.5	
15	7.59	-0.9	1087.1	108.7	18.9	1.9	

Viewpoint 3 Minor road near Wanside Rig junction

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Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	7.29	-2.1	384.9	38.5	7.3	0.7	X
3	5.79	-2.7	256.4	25.6	7.7	0.8	X
6	6.56	-2.2	356.7	35.7	8.3	0.8	X
8	5.67	-2.5	291.3	29.1	9.1	0.9	X
9	7.00	-2.4	309.1	30.9	6.3	0.6	X
14	5.32	-3.2	207.8	20.8	7.4	0.7	
15	4.39	-3.5	194.3	19.4	10.1	1.0	

Viewpoint 4 Watch Water Reservoir, Southern Upland Way

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	7.29	-1.9	448.4	44.8	8.4	0.8	
3	5.59	-2.4	309.1	30.9	9.9	1.0	
6	7.04	-1.8	483.7	48.4	9.8	1.0	
8	6.54	-1.8	483.7	48.4	11.3	1.1	
9	8.14	-1.9	448.4	44.8	6.8	0.7	
14	7.05	-2.0	413.2	41.3	8.3	0.8	
15	6.08	-2.1	384.9	38.5	10.4	1.0	

Viewpoint 5 Minor road near Wrunk Law

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	7.45	-0.9	1087.1	108.7	19.6	2.0	
3	6.54	-0.9	1087.1	108.7	25.4	2.5	
6	8.15	-0.7	1317.5	131.8	19.9	2.0	
8	8.53	-0.5	1582.1	158.2	21.7	2.2	
9	9.83	-0.8	1192.2	119.2	12.3	1.2	
14	10.05	-0.7	1317.5	131.8	13.0	1.3	
15	9.43	-0.6	1442.9	144.3	16.2	1.6	

Viewpoint 6 Spartleton Hill

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Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	10.70	-1.4	690.6	69.1	6.0	0.6	X
3	10.07	-1.6	576.0	57.6	5.7	0.6	X
6	9.57	-1.5	633.3	63.3	6.9	0.7	X
8	8.54	-1.5	633.3	63.3	8.7	0.9	X
9	8.65	-2.6	273.5	27.4	3.7	0.4	
14	6.88	-3.1	212.3	21.2	4.5	0.4	
15	6.84	-2.9	228.1	22.8	4.9	0.5	

Viewpoint 7 B6456, Westruther

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	11.64	-1.7	529.8	53.0	3.9	0.4	
3	10.41	-1.9	448.4	44.8	4.1	0.4	
6	10.68	-1.8	483.7	48.4	4.2	0.4	
8	9.63	-1.8	483.7	48.4	5.2	0.5	
9	10.46	-2.0	413.2	41.3	3.8	0.4	
14	8.49	-2.4	309.1	30.9	4.3	0.4	
15	7.91	-2.3	332.9	33.3	5.3	0.5	

Viewpoint 8 B6456 near Bedshiel

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	10.94	-1.0	982.0	98.2	8.2	0.8	
3	9.39	-1.1	902.2	90.2	10.2	1.0	
6	10.23	-0.9	1087.1	108.7	10.4	1.0	
8	9.33	-0.9	1087.1	108.7	12.5	1.2	
9	10.60	-1.1	902.2	90.2	8.0	0.8	
14	8.80	-1.2	822.4	82.2	10.6	1.1	
15	7.94	-1.2	822.4	82.2	13.0	1.3	

Viewpoint 9 Dirrington Great Law

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.00	-0.4	1721.2	172.1	26.9	2.7	
3	9.70	-0.3	1851.6	185.2	19.7	2.0	
6	8.53	-0.2	1981.9	198.2	27.3	2.7	
8	9.42	-0.1	2083.6	208.4	23.5	2.3	
9	8.33	-0.5	1582.1	158.2	22.8	2.3	
14	10.29	-0.3	1851.6	185.2	17.5	1.8	
15	10.96	-0.2	1981.9	198.2	16.5	1.7	

Viewpoint 10 Lammer Law

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	11.73	-1.2	822.4	82.2	6.0	0.6	
3	12.31	-1.1	902.2	90.2	6.0	0.6	
6	10.80	-1.2	822.4	82.2	7.1	0.7	
8	10.32	-1.2	822.4	82.2	7.7	0.8	
9	9.12	-1.7	529.8	53.0	6.4	0.6	
14	8.89	-1.6	576.0	57.6	7.3	0.7	
15	9.70	-1.3	756.5	75.7	8.0	0.8	

Viewpoint 11 Edgarhope Wood, Southern Upland Way

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	13.51	-1.3	756.5	75.7	4.1	0.4	
3	11.92	-1.4	690.6	69.1	4.9	0.5	
6	12.85	-1.2	822.4	82.2	5.0	0.5	
8	11.96	-1.2	822.4	82.2	5.8	0.6	
9	13.25	-1.2	822.4	82.2	4.7	0.5	X
14	11.45	-1.3	756.5	75.7	5.8	0.6	X
15	10.59	-1.2	822.4	82.2	7.3	0.7	X

Viewpoint 12 Minor road near Hen Law

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	16.90	-1.2	822.4	82.2	2.9	0.3	
3	15.67	-1.3	756.5	75.7	3.1	0.3	
6	15.93	-1.2	822.4	82.2	3.2	0.3	
8	14.87	-1.2	822.4	82.2	3.7	0.4	
9	15.60	-1.4	690.6	69.1	2.8	0.3	
14	13.63	-1.5	633.3	63.3	3.4	0.3	
15	13.12	-1.5	633.3	63.3	3.7	0.4	

Viewpoint 13 A6015 near Greenlaw

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	16.00	-1.2	822.4	82.2	3.2	0.3	
3	16.91	-1.1	902.2	90.2	3.2	0.3	
6	15.25	-1.1	902.2	90.2	3.9	0.4	
8	14.99	-1.0	982.0	98.2	4.4	0.4	X
9	13.57	-1.4	690.6	69.1	3.7	0.4	
14	13.80	-1.3	756.5	75.7	4.0	0.4	
15	14.69	-1.2	822.4	82.2	3.8	0.4	

Viewpoint 14 B6362 above Lauder

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux10-6) at 10%	Obscured
1	14.65	-1.5	633.3	63.3	3.0	0.3	
3	15.14	-1.4	690.6	69.1	3.0	0.3	
6	15.78	-1.3	756.5	75.7	3.0	0.3	
8	16.75	-1.1	902.2	90.2	3.2	0.3	M
9	17.12	-1.3	756.5	75.7	2.6	0.3	
14	18.48	-1.2	822.4	82.2	2.4	0.2	
15	18.38	-0.9	1087.1	108.7	3.2	0.3	X

Viewpoint 15 Traprain Law

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	16.68	-1.5	633.3	63.3	2.3	0.2	X
3	17.86	-1.6	576.0	57.6	1.8	0.2	X
6	17.73	-0.6	1442.9	144.3	4.6	0.5	X
8	18.81	-0.3	1851.6	185.2	5.2	0.5	X
9	18.50	-1.1	902.2	90.2	2.6	0.3	X
14	20.31	-0.6	1442.9	144.3	3.5	0.3	X
15	20.59	-0.4	1721.2	172.1	4.1	0.4	X

Viewpoint 16 Park Lane, Haddington

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	18.15	-1.3	756.5	75.7	2.3	0.2	
3	19.18	-1.2	822.4	82.2	2.2	0.2	
6	19.24	-0.8	1192.2	119.2	3.2	0.3	X
8	20.30	-0.5	1582.1	158.2	3.8	0.4	X
9	20.14	-1.2	822.4	82.2	2.0	0.2	X
14	21.88	-0.6	1442.9	144.3	3.0	0.3	X
15	22.07	-0.6	1442.9	144.3	3.0	0.3	X

Viewpoint 17 Barney Hill, Garleton Hills

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	20.66	-1.2	822.4	82.2	1.9	0.2	
3	19.02	-1.2	822.4	82.2	2.3	0.2	
6	20.64	-1.1	902.2	90.2	2.1	0.2	
8	20.25	-1.1	902.2	90.2	2.2	0.2	M
9	21.85	-1.2	822.4	82.2	1.7	0.2	
14	20.72	-1.2	822.4	82.2	1.9	0.2	M
15	19.74	-1.1	902.2	90.2	2.3	0.2	M

Viewpoint 18 A6112 near Fawcett Wood

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	24.90	-1.2	822.4	82.2	1.3	0.1	M
3	23.61	-1.3	756.5	75.7	1.4	0.1	
6	23.95	-1.2	822.4	82.2	1.4	0.1	M
8	22.89	-1.2	822.4	82.2	1.6	0.2	M
9	23.64	-1.4	690.6	69.1	1.2	0.1	
14	21.67	-1.4	690.6	69.1	1.5	0.1	
15	21.16	-1.4	690.6	69.1	1.5	0.2	

Viewpoint 19 A697 near Coldstream

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	22.27	-1.1	902.2	90.2	1.8	0.2	X
3	23.81	-0.7	1317.5	131.8	2.3	0.2	X
6	23.07	-0.8	1192.2	119.2	2.2	0.2	X
8	24.08	-0.4	1721.2	172.1	3.0	0.3	X
9	23.21	-1.1	902.2	90.2	1.7	0.2	X
14	25.18	-0.7	1317.5	131.8	2.1	0.2	X
15	25.75	-0.5	1582.1	158.2	2.4	0.2	X

Viewpoint 20 B6371, Tranent

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux$^{10-6}$)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	27.69	-0.5	1582.1	158.2	2.1	0.2	
3	27.87	-0.4	1721.2	172.1	2.2	0.2	
6	26.64	-0.4	1721.2	172.1	2.4	0.2	
8	25.90	-0.4	1721.2	172.1	2.6	0.3	
9	25.06	-0.5	1582.1	158.2	2.5	0.3	
14	24.22	-0.5	1582.1	158.2	2.7	0.3	
15	24.73	-0.5	1582.1	158.2	2.6	0.3	

Viewpoint 21 Eildon North Hill

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	24.49	-1.0	982.0	98.2	1.6	0.2	
3	25.02	-1.0	982.0	98.2	1.6	0.2	
6	25.63	-0.9	1087.1	108.7	1.7	0.2	
8	26.61	-0.9	1087.1	108.7	1.5	0.2	
9	26.91	-1.0	982.0	98.2	1.4	0.1	
14	28.34	-0.9	1087.1	108.7	1.4	0.1	
15	28.25	-0.9	1087.1	108.7	1.4	0.1	

Viewpoint 22 North Berwick Law

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	25.25	-1.3	756.5	75.7	1.2	0.1	
3	26.10	-1.2	822.4	82.2	1.2	0.1	
6	26.37	-1.2	822.4	82.2	1.2	0.1	
8	27.42	-0.9	1087.1	108.7	1.4	0.1	X
9	27.41	-0.9	1087.1	108.7	1.4	0.1	X
14	29.07	-0.8	1192.2	119.2	1.4	0.1	X
15	29.16	-0.9	1087.1	108.7	1.3	0.1	X

Viewpoint 23 A198, Dirleton

Turbine	Distance (km)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux^{10-6})	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	27.40	-0.3	1851.6	185.2	2.5	0.2	
3	29.01	-0.3	1851.6	185.2	2.2	0.2	
6	27.38	-0.3	1851.6	185.2	2.5	0.2	
8	27.82	-0.3	1851.6	185.2	2.4	0.2	
9	26.24	-0.4	1721.2	172.1	2.5	0.2	
14	27.64	-0.3	1851.6	185.2	2.4	0.2	
15	28.60	-0.3	1851.6	185.2	2.3	0.2	

Viewpoint 24 Torfichen Hill

Appendix B – Abbreviations and Definitions

ADSB…………………………………..………Automatic Dependent Surveillance Broadcast
AGL..Above Ground Level (Height)
ANO...Air Navigation Order
AMSL...Above Mean Sea Level (Elevation)
ASG..Aviation Steering Group
CAA...Civil Aviation Authority
CAP..Civil Aviation Publication (Referrers to Specific Documents)
cd...Candela, a measure of light intensity
DIO..Defence Infrastructure Organisation
HNTA...Helicopter Night Training Area
In Flight Visibility....................The distance a pilot can see ahead to fly & navigate the aircraft
IR...Infra-Red
Kts...Knots: a measure of airspeed (10 kts = 12mph = 19 kph)
LED...Light Emitting Diode
MOD...Ministry of Defence
mW/sr..............milliWatts per steradian: electromagnetic energy output related to solid angle
Nm..Nautical Mile
NVD ....Night Vision Devices - Aircraft Mounted
NVG...Night Vision Goggles - Operator Worn
Radar Altimeter........An altimeter that uses radar to accurately measure height above ground
QFE ....Setting on Altimeter that gives Height above Airfield
RoAR...Rules of the Air Regulations
Rule 5...The Low Flying Rule – part of RoAR
Rule 28...VFR Rules Outside Controlled Airspace – part of the RoAR
ReUK...Renewables UK – The UK Wind Industry Body
SAR Box..Night Training Area for Search and Rescue Helicopter Units
SSA..Sector Safety Altitude
SSR……………………………………………………………Secondary Surveillance Radar
UKAB...............................United Kingdom Air Prox Board – Investigates Aircraft Near Misses
VFR....................................Visual Flight Rules (Flight without ATC on a see-and-be-seen basis)
VMC..................................Visual Meteorological Conditions (Weather suitable for VFR flight)

Hazards, 38 Hadrian Way, Chilworth, Southampton SO16 7HX

Appendix C CAA Response

Safety and Airspace Regulation Group
Safety and Business Delivery

Civil Aviation Authority

Mike Hale
Aviation Consultant
Wind Power Aviation Consultants Ltd.
38 Hadrian Way
Chilworth
Southampton
SO16 7HX

13 March 2023
Ref Windfarms/Dunside

Dear Mike,

Proposed Obstacle Lighting Scheme for Dunside Wind Farm

Reference: Dunside Wind Farm Brief dated 27 February 2023

1. Thank you for the e-mail at reference. The attached report discusses the proposed obstacle lighting plan for the Dunside Wind Farm.

2. The proposed Dunside Wind Farm consists of 15 turbines, with tip heights 220m above ground level, which brings them within scope of the Air Navigation Order (ANO) Article 222 obstacle lighting requirements.

3. We have considered the report carefully and take note of the intent to address concerns relating to adverse visual impacts of aviation lighting on non-aviation receptors while ensuring that the lighting installed on the turbines meets air safety requirements.

4. We note the shape of the proposed wind farm, the topography and that some mitigation is proposed to be provided by the provision of infra-red lighting for those operators who carry Night Vision Device capability.

5. Under provisions given in the Air Navigation Order (ANO) Article 222 section 6, the CAA provides for the following variation:

- medium intensity steady red (2000 candela) lights on the nacelles of turbines T01, T03, T06, T08, T09, T14 and T15;
- a second 2000 candela light on the nacelles of the above turbines to act as alternates in the event of a failure of the main light;

Civil Aviation Authority
1W Aviation House Beehive Ring Road Crawley West Sussex RH6 0YR www.caa.co.uk
Telephone [redacted]

• the lights on these turbines to be capable of being dimmed to 10% of peak intensity when the lowest visibility as measured at suitable points around the wind farm by visibility measuring devices exceeds 5km;

• infra-red lights to MoD specification installed on the nacelles of turbines T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T11, T12, T13, T14 and T15.

6. Intermediate level 32 candela lights are not required to be fitted on the turbine towers.

7. If the proposed design of the wind farm changes (other than variations due to micrositing etc.) this is likely to require a revision to this aviation obstacle lighting variation.

8. Please let me know if you have any further queries.

Yours sincerely,

[redacted]

Andy Wells, Manager Rulemaking and Safety Publications

Continued (2 of 2 pages)

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