Appendix 16.1: Aviation Lighting and Mitigation Report

This page is intentionally blank.

Wind Power Aviation Consultants Ltd

Shepherds' Rig Aviation Lighting and Mitigation Technical Appendix V1.2

Our Reference: WPAC 022/26
Your Reference: Shepherds' Rig EIA

Authors: Sam Taylor BA (Hons) MSc

Squadron Leader Mike Hale MBE MSc CFS RAF (Ret)

Edited and Released by Commander John Taylor, RN (Ret)

Wind Power Aviation Consultants Ltd, Company No.: 6811887
e-mail: enquiries@wpac.co.uk Tel.: +44 (0)2380767345 Mob.: +44 (0)7949234440
www.wpac.co.uk

Reference Documents

A. Civil Aviation Publication (CAP) 764 Civil Aviation Authority (CAA) Policy and Guidance on Wind Turbines Edition 7, Dec 2025
B. Air Navigation Order (ANO) Article 222
C. 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.
D. International Civil Aviation Organisation (ICAO) Annex 14 Vol 1 Chapter 6
E. MOD Obstruction Lighting Guidance Document 01 Jan 2020
F. Landscape Institute Guidance on Landscape and Visual Impact Assessment Version 3
G. NatureScot Guidance on Aviation Lighting Impact Assessment dated November 2024

Scope

1. This report is divided into two parts. Part 1 proposes a lighting design that is compliant with the regulations and guidance contained within References A to G. It explains the rationale behind the lighting design when considering 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. 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 and can be used to inform the Landscape and Visual Impact Assessment as recommended in the guidance laid down in the Landscape Institute's Guidelines for Visual Impact Assessment Version 3 (GLVIA3) and the Naturescot guidance at Reference G.

Part 1 Turbine Lighting Layout Design

Introduction

2. WPAC have designed a large number of CAA and MOD compliant lighting layouts for wind farms and have engaged with the CAA regarding the changes now incorporated into the latest version of CAP 764 (Reference A) in terms of aviation lighting requirements and potential mitigation options. The previous versions of CAP 764 and the various drafts issued over the past several years have now been fully incorporated into the latest version released at the end of 2025 and this report has been written taking into account those changes, most significantly regarding changes in guidance relating to any requirement for and operation of an Aviation Detection Lighting Systems (ADLS).

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

Lighting Layout Starting Point and Assumptions

3. The Proposed Varied Development consists of 11 turbines with a tip height of 220m and is located 10km north of St John's Town of Dalry and 2km to the east of the Glenkens (A713) valley. Shepherds' Rig sits on the high ground formed by Craigengillan and Marscalloch hills and is set back from the immediate area of the valley. A development with turbines with a tip height in excess of 150m above ground level (AGL) requires both CAA ANO visible red and MOD infra-red obstruction lighting.

4. From a civilian aviation perspective, the Proposed Development is located under the Scottish Terminal Airspace (TMA) which has a base of 5500ft above mean sea level (AMSL). The airspace below the TMA, and around Shepherds' Rig, is designated as unregulated Class G. From a military perspective, the turbines will be located in Low Flying Area (LFA) 16; one of the busiest LFAs in the UK. In addition, Shepherds' Rig is in the Tactical Training Area (TTA) 20 where military fast jet aircraft operate down to 100ft (30m) day and night.

5. In the hours of darkness this area converts to Night Allocated Region (NAR) 2B. Although primarily a fast jet training area the airspace is also used by MOD and NATO tactical transport aircraft and helicopters for day and night training. In addition, this area will be frequented by Coastguard Search and Rescue (CSAR), Police, Helicopter Emergency Medical Services (HEMS) and Air Ambulance helicopters as well as military craft by day and night. This type of activity dictates that the site will require visible red and infra-red obstruction lighting on its turbines.

Lighting Assessment Overview

6. Taking into account the classification of the airspace and the aviation operations that take place in the area, lighting requirements for the proposed development will be assessed in accordance with Class G 'en-route' airspace requirements as detailed in CAP 764 (Reference A)

- To accommodate MOD requirements the site will be assessed for NVG compatible lighting in accordance with MOD published obstruction lighting specifications.

- Where possible the recommended final lighting configuration will be optimised to reduce light impact on the local area.

- CAA obstruction lighting dispensations that are currently offered where flight safety can be maintained will be included.

- The proposed development consists of 11 turbines at 220m to tip.

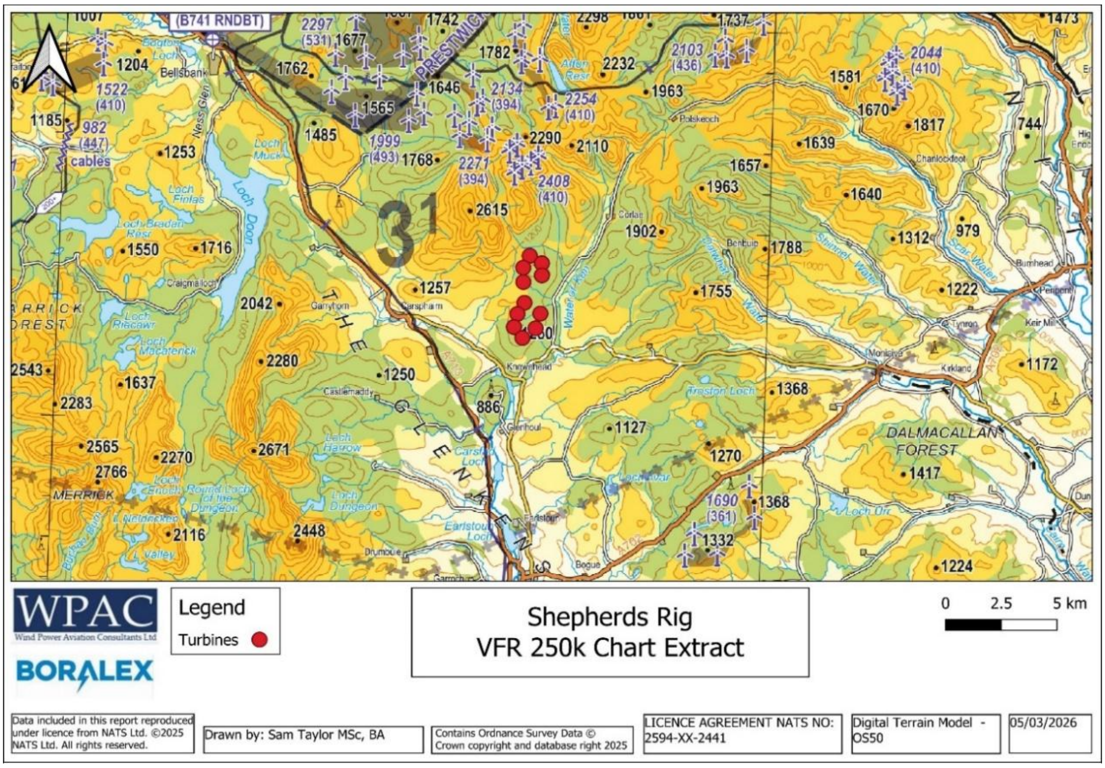


Figure 1 Shepherds' Rig on an aviation chart

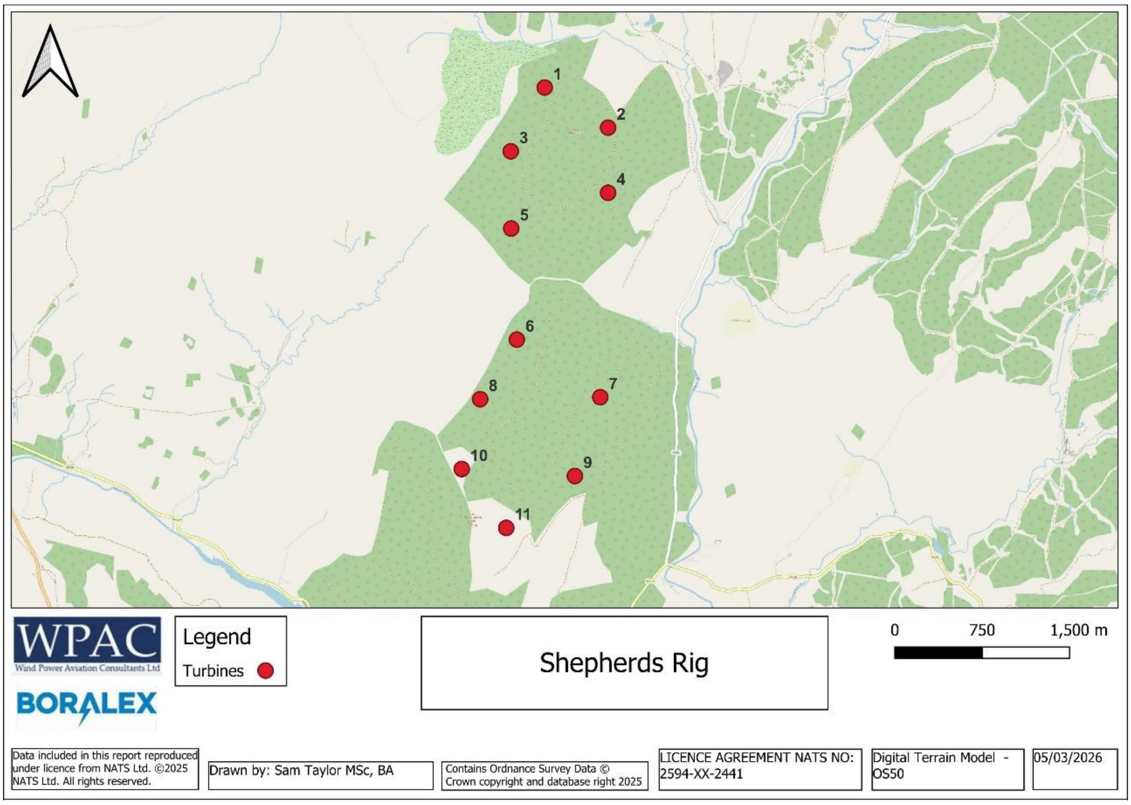


Figure 2 Shepherds' Rig

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

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

7. In accordance with the CAP 764 conditions, the CAA requires:

- That all 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 turbines is less than 900m total. NB: additional spacing dispensation is sometimes available for the above criteria.
- That any unlit turbine does not exceed a 10° up-slope from adjacent lit turbines.
- No turbine shall be more than 1800m (1nm) from a lit turbine.
- Note: At Shepherd's Rig, all turbines are deemed perimeter turbines, as defined by the CAP 764, and will require an ANO light.

8. Applying these criteria dictates that without any dispensations all 11 turbines will require ANO visible red lighting.

Turbines with 2000/200cd Lights: T1, T2, T3, T4, T5, T6, T7, T8, T9, T10, and T11.

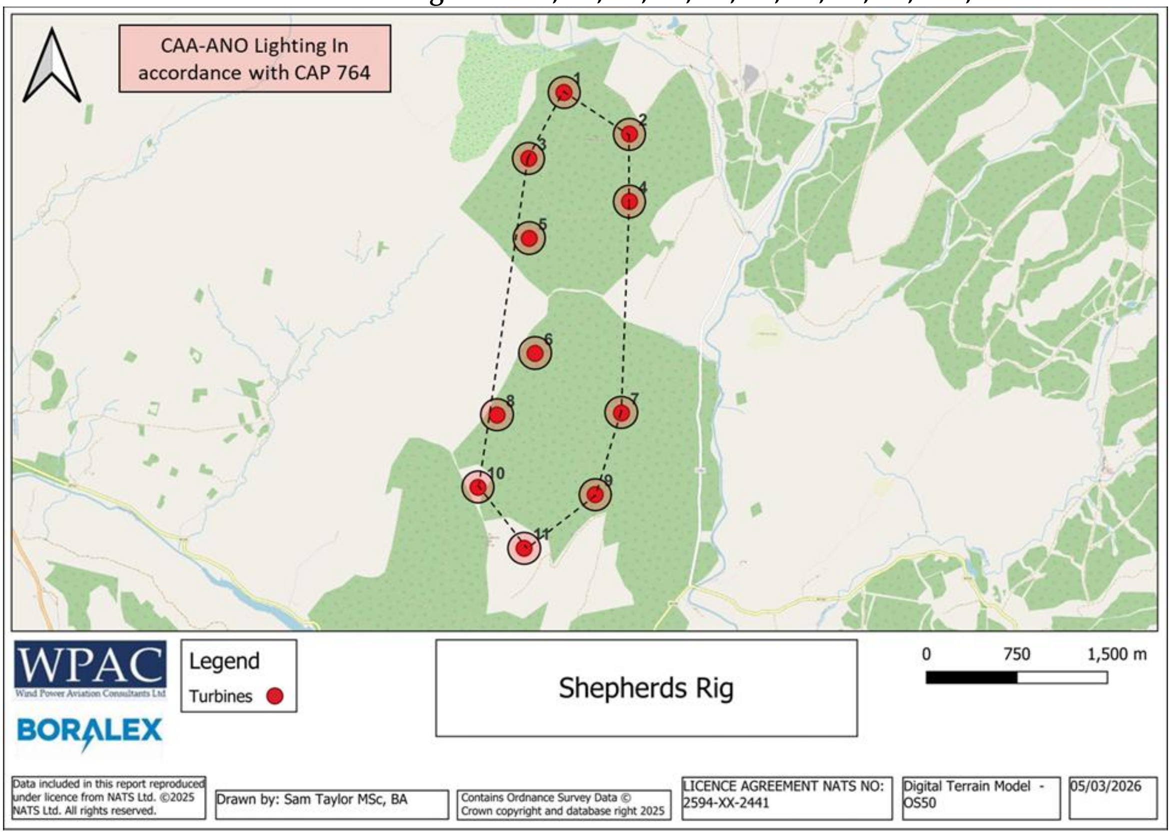


Figure 3 Lighting Layout without CAA Dispensations

CAA-ANO Red 2000/200cd Reduced Lighting Proposal

9. The military have operated at low level at night for many decades now using night vision equipment. In the last decade, more civilian operators have moved to night low level using suitable night vision equipment: night vision goggles (NVGs) etc; such civilian operators include CSAR, Police, HEMS and Air Ambulance.

10. Although, in the past, some night operators would fly at night at low level without night equipment (on carefully pre-planned exercises pre-flown by day) such events have been overtaken by the ever-widening use of night vision equipment. As a result, operators who now night fly without night vision equipment will fly at or above 'safety altitude' when not under the guidance of Air Traffic Control.

11. Aircraft operating at safety altitude or above and depending upon the protocol adopted or phase of flight, the safety altitude used will be 1000ft (300m), 1500ft (450m) or 2000ft (600m) above the local terrain/highest obstacle, this includes the turbine tip heights. Aircraft/helicopters flying as such, will only need enough visible lights to define the wind farm and its size/shape/perimeter.

12. Accordingly, aircraft flying above the turbines at safety altitude or above and/or under ATC control will only require an outline of the proposed development. Such a requirement could be met with **six** visible red lights on turbines **T1, T4, T5, T6, T7 and T11**.

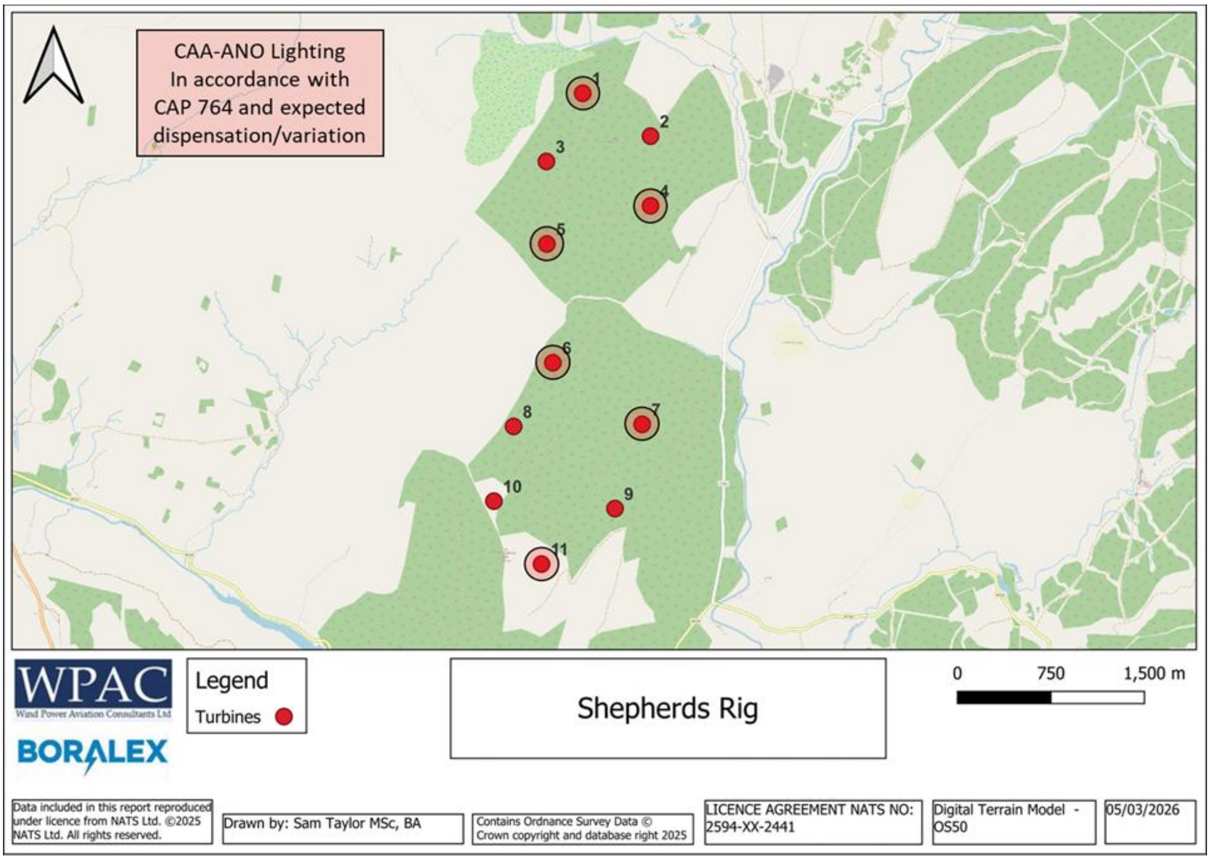


Figure 4 CAA-ANO Lighting Arrangement (including CAA dispensations).

MOD Lighting Requirements

13. 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.

14. 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.

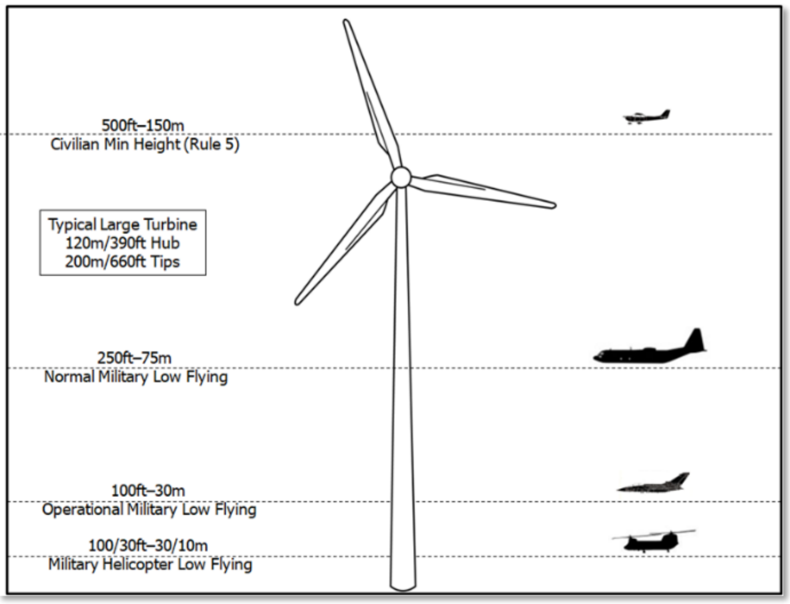


Figure 5 Wind turbine in context with MOD Low Flying

MOD Infrared Lighting Layout

15. The MOD requires:

- That all 'compound-perimeter' turbines (see blue dotted line) 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 all turbines are lit.
- The proposed development exceeds the MOD small site criteria (red dotted circle). Accordingly, central (non-perimeter) turbines can remain unlit. Shepherds' Rig meets this criterion; however, the site does not have central turbines as all will be deemed compound perimeter turbines.

16. Applying these criteria dictates that all 11 turbines of the proposed development site will require IR lighting.

Turbines with IR Lighting: T1, T2, T3, T4, T5, T6, T7, T8, T9, T10 and T11.

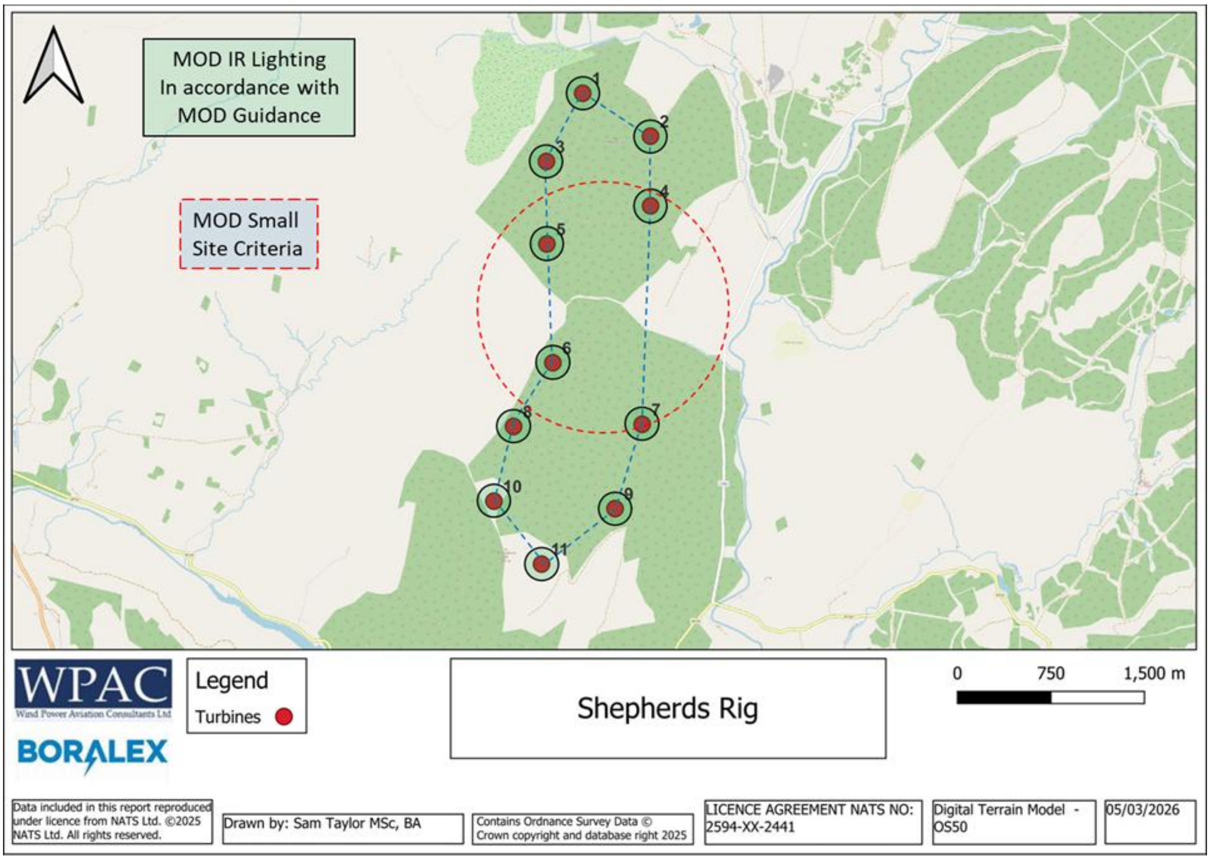


Figure 6 Proposed MOD Infrared Lighting Arrangement

Combined CAA Visible Lighting and MOD Infrared Lighting

Shepherds' Rig Turbine Lighting Table							
Turbine	**Easting**	**Northing**	**Tip Ht**	**Rotor**	**Hub Ht**	**CAA-ANO**	**MOD-IR**
1	262208	595979	220m	163m	138.5m	2000/200cd	600mW/sr
2	262752	595635	220m	163m	138.5m		600mW/sr
3	261917	595432	220m	163m	138.5m		600mW/sr
4	262752	595076	220m	163m	138.5m	2000/200cd	600mW/sr
5	261921	594770	220m	163m	138.5m	2000/200cd	600mW/sr
6	261969	593817	220m	163m	138.5m	2000/200cd	600mW/sr
7	262685	593323	220m	163m	138.5m	2000/200cd	600mW/sr
8	261654	593306	220m	163m	138.5m		600mW/sr
9	262467	592647	220m	163m	138.5m		600mW/sr
10	261496	592707	220m	163m	138.5m		600mW/sr
11	261878	592202	220m	163m	138.5m	2000/200cd	600mW/sr

Table 1 CAA and MOD Lighting Arrangement

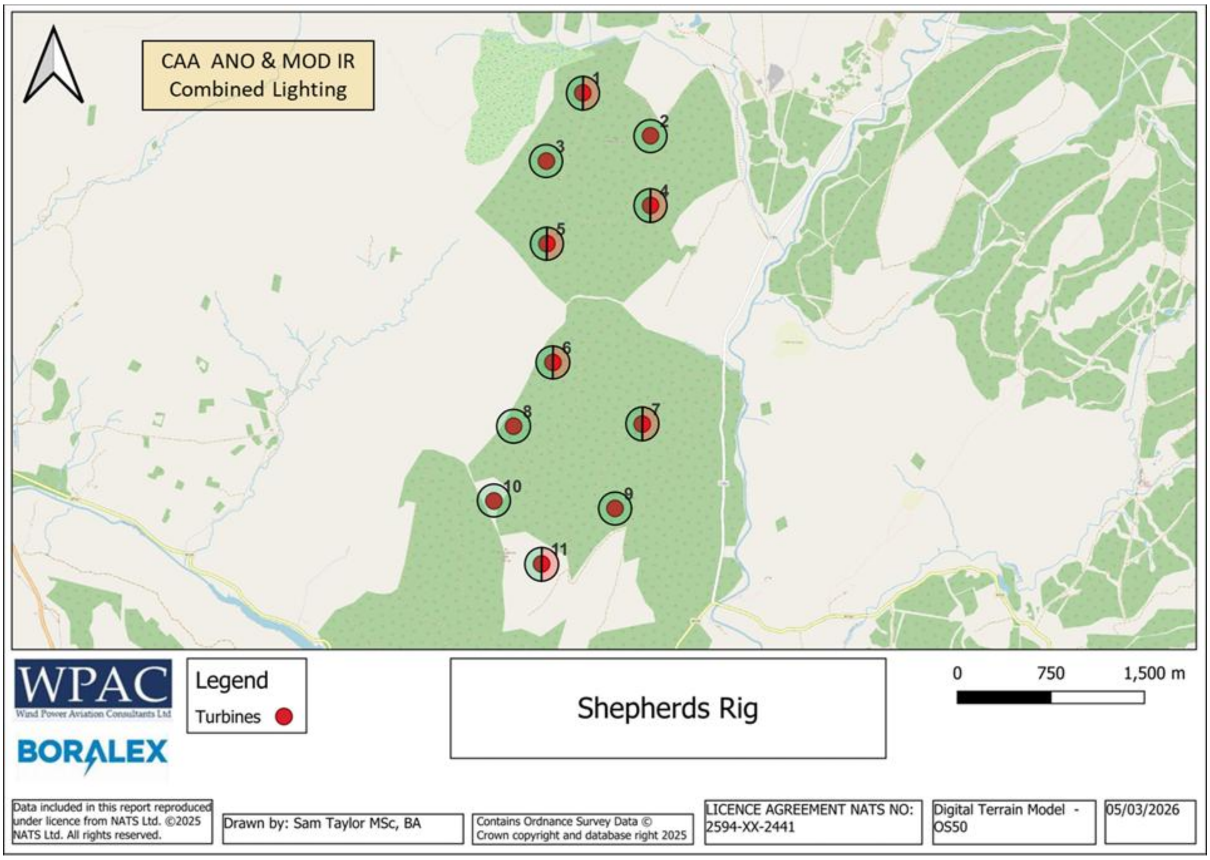


Figure 7 CAA-ANO Visible Red and MOD Infrared Lighting Arrangement

ANO Light Specifications

17. The ANO 2000/200cd lights will conform to the ICAO specification as set out in Annex 14 Table 6-3. 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.

18. **<u>Low Intensity Mid Mast Lights</u>** – 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.

19. 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 proposed that the CAA guidance requirement for 32cd (Type B) mid mast lights be removed for Shepherds' Rig. The CAA have agreed that intermediate lighting is not required as reflected in their lighting reduction concession approval letter attached at Appendix C to this report.

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

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

20. 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

21. 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

22. 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-WT-MIC[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 interpolated to every 0.1°. This light is a finely tuned upgrade to the previous version and has been developed specifically for onshore wind turbine lighting in order to minimise downward light intensity and is now available from the manufacturer.

23. 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.

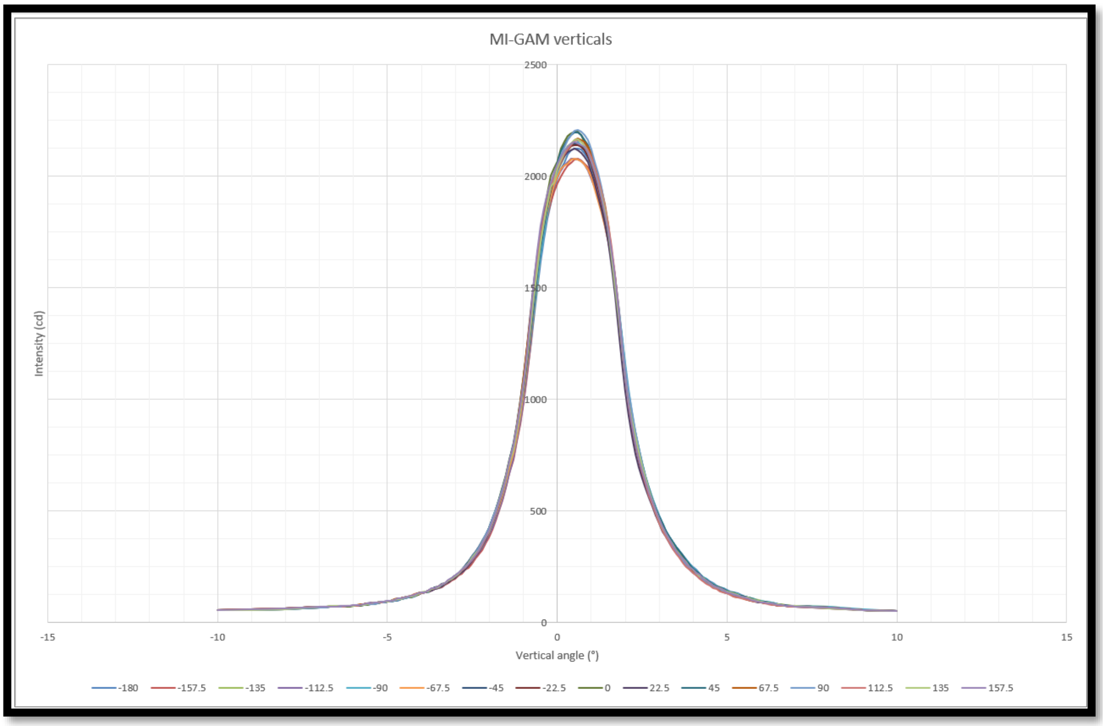


Figure 8 (MI GAM CEL-WT-MIC Light Measurement Results)

[1] Candela is the SI Unit of luminous intensity and refers to the amount of light emitted in a particular direction.
[2] CEL-WT-MIC - rev1.pdf

24. 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 138.5m. 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 designated Shepherds' Rig viewpoints. The locations of the viewpoints are shown in Figure 9 and Table 5.

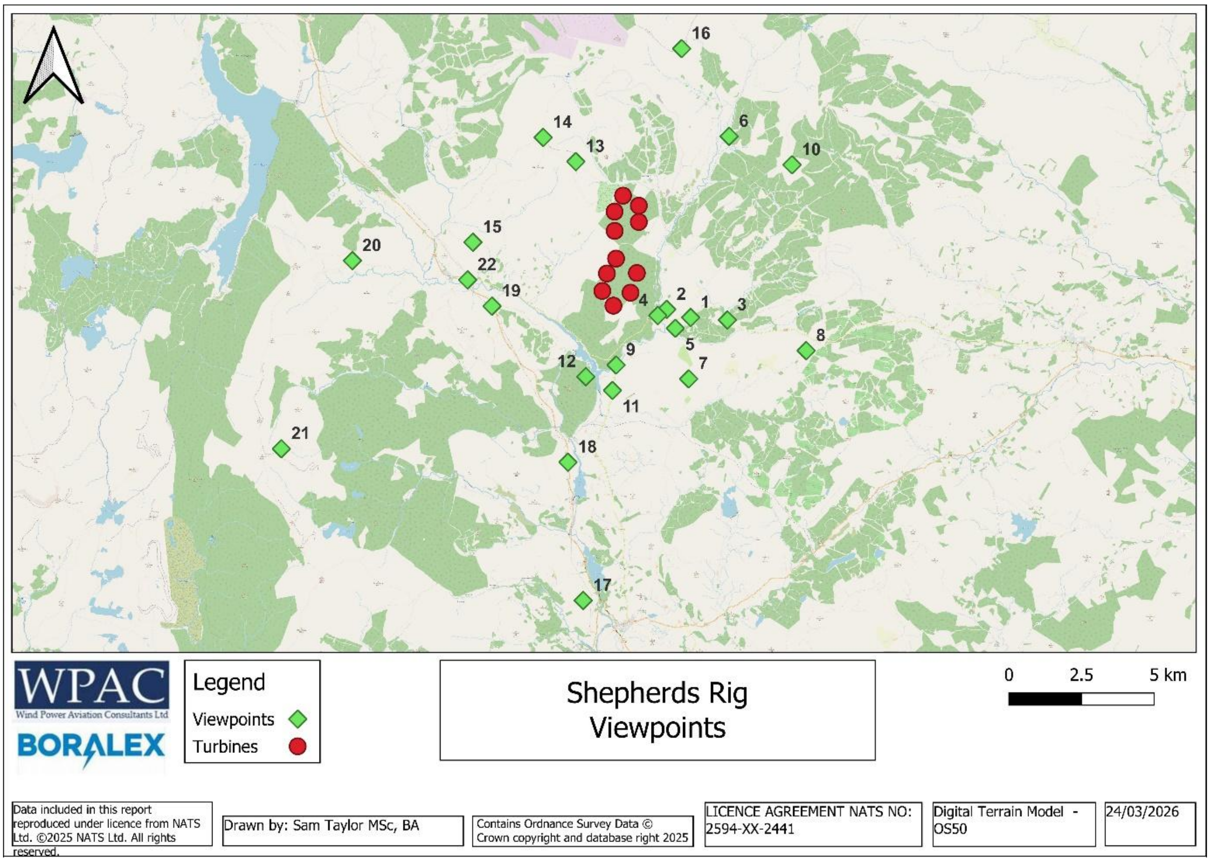


Figure 9 Viewpoint Locations

25. 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$^{(10\text{-}6)}$/m^2) or lux$^{(10\text{-}6)}$. 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.

26. 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	Position
1	Stroanfreggan Bridge (B729)	NX 64537 91795
2	Stroanfreggan Craig	NX 63712 92073
3	Guttery Glen (B729)	NX 65802 91708
4	Smittons Bridge	NX 63405 91862
5	Stroanfreggan Cairn	NX 64008 91424
6	Head of Ken Valley	NX 65861 98017
7	Southern Upland Way at Culmark Hill	NX 64468 89685
8	Minor Road south of B729	NX 68514 90655
9	High Bridge of Ken	NX 61971 90162
10	Southern Upland Way, Benbrack (Striding Arch)	NX 68026 97039
11	B7000 at East Arndarroch	NX 61845 89289
12	Dundeugh Hill	NX 60928 89761
13	Beninner	NX 60584 97150
14	Cairnsmore of Carsphairn	NX 59460 97979
15	Craig of Knockgray	NX 57042 94380
16	Alhang	NS 64227 01029
17	Southern Upland Way at Waterside Hill	NX 60837 82074
18	A713 at Stroangassel	NX 60314 86823
19	A713 south of Carsphairn	NX 57699 92185
20	Woodhead Mines	NX 52893 93746
21	Corserine (Hennessey's Shelter)	NX 50448 87285
22	Carsphairn War Memorial	NX 56859 93087

Table 5 Viewpoints

Interpreting the Results

27. 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 m² (Lux $^{(10-6)}$) at each viewpoint.

Viewpoint	Turbine	Distance (KM)	Microlumens per m2 (lux10-6)	Microlumens at 10%	Obscured
1	11	2.69	12.6	1.3	
2	7	1.62	29.9	3.0	
3	7	3.51	23.0	2.3	
4	11	1.56	30.7	3.1	
5	7	2.31	17.6	1.8	
6	7	5.67	20.0	2.0	
7	7	4.05	43.1	4.3	
8	7	6.41	38.4	3.8	
9	11	2.04	18.0	1.8	
10	1	5.91	60.5	6.1	
11	7	4.12	14.4	1.4	
12	7	3.97	15.5	1.6	
13	1	2	21.9	2.2	
14	11	6.26	10.9	1.1	
15	5	4.9	60.6	6.1	
16	11	9.13	23.4	2.3	
17	7	11.4	6.6	0.7	
18	7	6.92	7.3	0.7	
19	7	5.11	13.4	1.3	
20	7	9.8	16.5	1.6	
21	11	12.44	11.3	1.1	
22	7	5.83	11.1	1.1	

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

28. 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/LED 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

29. 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	Turbine	Distance (KM)	Candela	Candela at 10%	Obscured
1	11	2.69	91	9	
2	5	3.24	154	15	
3	5	4.94	350	35	
4	1	4.29	128	13	
5	5	3.94	158	16	
6	7	5.67	642	64	
7	7	4.05	706	71	
8	7	6.41	1580	158	
9	4	4.98	176	18	
10	1	5.91	2117	212	
11	5	5.48	304	30	
12	7	3.97	245	24	
13	4	3	145	14	
14	11	6.26	429	43	
15	7	5.74	1934	193	
16	11	9.13	1955	195	
17	7	11.4	858	86	
18	7	6.92	350	35	
19	7	5.11	350	35	
20	7	9.8	1580	158	
21	1	14.62	2006	201	
22	7	5.83	378	38	

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

Part 2 Mitigation

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

30. 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.

31. 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'.*

32. 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.

33. It will be helpful to calculate how much time the lights would spend at 2000cd and at 200cd. To assess historical visibility in the area, reference is made to the closest meteorological station to the proposed development, in this case it is located at Prestwick Airport. Note: there are no meteorological stations that publish meaningful historical data closer to Shepherds' Rig. However, although the visibility at Prestwick will not be identical to Shepherds' Rig it will invariably be in the same air-mass for the majority of the time and will give similar observations over the longer period.

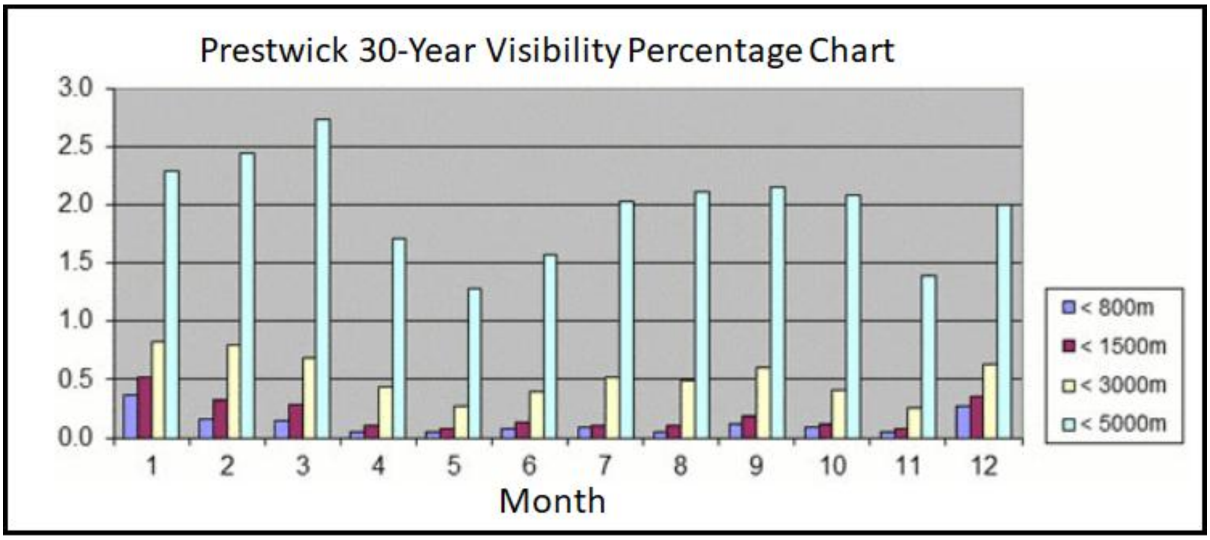


Table 9 Prestwick Visibility

34. This Met Office table shows that the visibility is below 5km (light blue bar) for an average of around 2% of the time. This suggests that the Shepherds' Rig turbine lights will be at an average of **2000cd for 2% of the time and 200cd for 98% of the time.**

35. In addition, visibility improves with height since the concentration of particles (dust, haze) and liquid droplets (water) reduces with height and the air also becomes thinner. It could be argued that the Shepherds' Rig visibility, on terrain that is approximately 300-350AMSL, will be better than that at Prestwick.

Obstruction Light Weather Obscuration.

36. On occasion, the visibility in the area of Shepherds' Rig will reduce significantly due to the presence of cloud on the hills. If the turbines are in cloud, then the obstruction lights will not be seen. The turbines will carry the CAA/ANO lights on the turbine hub. The average height at the base of these turbines is around 1000-1100ft above mean sea level (AMSL). The hub heights for the proposed turbines will be around 370ft AGL giving hub heights averaging around 1400ft AMSL. For aeronautical reasons meteorological cloud bases are quoted in feet (ft).

37. It is now possible to compare the average **turbine hub/light** height of **1400ft** AMSL with the actual cloud bases recorded by the Met Office at Prestwick Airport, again, over a 30-year period as shown in Table 10.

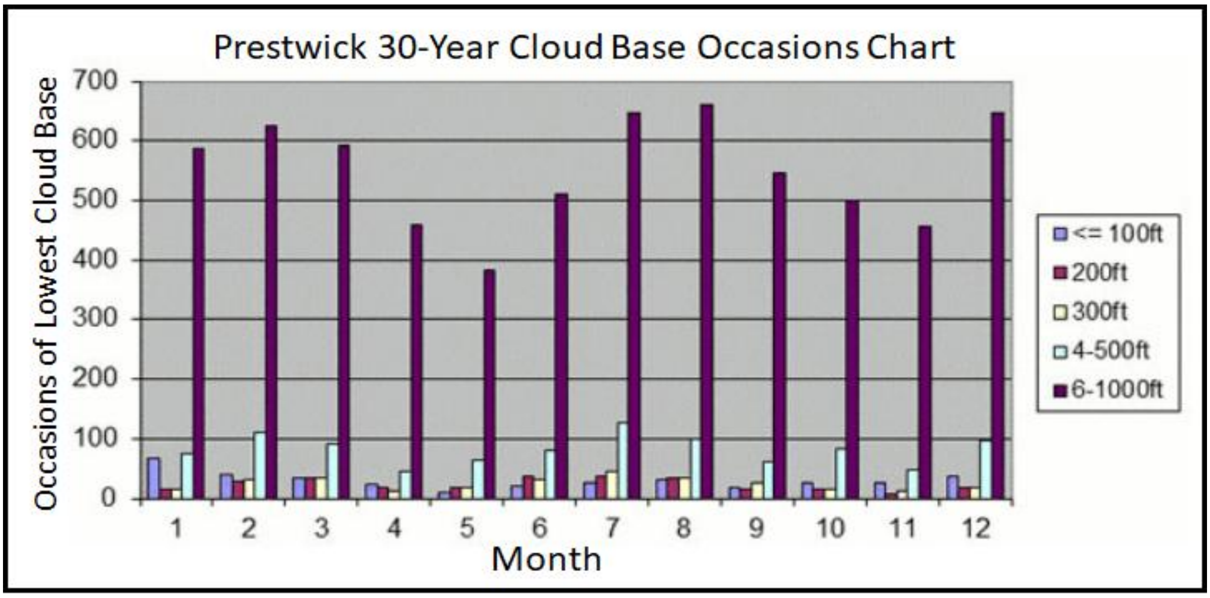


Table 10 Prestwick Cloud Base

38. The burgundy columns (600-1000ft) indicate that the cloud base will range from approximately 600-1000ft below turbine hub heights on around 550 occasions a month. At this distance below the turbine hubs the lights will be completely obscured. The other columns (light blue in particular, 400-500ft) indicate that on a further 200 occasions a month the lights will be completely obscured by cloud. Note: Met Office statistics report cloud base in occurrences as opposed to total duration.

39. Whilst Prestwick is not Shepherds' Rig, Met Office statistics show that the cloud base reduces in the region of hills. It could be argued that at Shepherds' Rig, located on a 350m hill, the cloud-base would be lower than at Prestwick thus providing even greater degree of light obscuration than calculated here.

Weather Obscuration Conclusion

40. 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 that the information for Shepherds' Rig, so gathered, should be presented as follows:

> *Meteorological observations suggest that the turbine hubs will be obscured around 750 occasions a month by cloud.* *(Obstruction lights not visible to the public)*
>
> *When not obscured by cloud, the visibility in the area of the turbines can be expected to exceed 5km for up to 98% of the time.* *(Obstruction lights switched down to 200cd)*

Conclusion/Notes

41. The purpose of this report is to identify an obstruction lighting arrangement that will have the minimum effect upon the environment but at the same time is a safe design for night low level operators. This has been accomplished by using a combination of CAA ANO and MOD IR lights.

42. Applying the CAP 764 Draft criteria for visible red obstruction lighting results in a lighting solution that requires six turbines to carry a visible red ANO light. By applying current CAA dispensations and then matching the lighting to the operators that will require night visible lighting, minimal but aviation safe layout was achieved. This results in a total of:

6 x ANO Red 2000/200cd lights and 11 x MOD IR 600mW/sr lights.

43. Furthermore, the site is in an area where it will benefit from 90% light-dimming in good weather and obscuration of both turbines and the visible ANO lighting in poor weather.

The lights will be regularly obscured by cloud and when not obscured set at the lower 200cd for approximately 98% of the time.

44. The CAA currently state: '*met visibility should be measured at suitable points around the wind farm*. In the case of the Shepherds' Rig turbines: Visibility Meters on **T1, T6, and T11** will meet this criterion.

Technical Mitigation

45. One other form of potential mitigation commonly discussed is the installation of an Aviation 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. Whilst some progress has been made there are still some significant technical issues to be overcome and the requirement to install an ADLS system should only be considered where even the reduced lighting scheme defined in Section 1 of this report would be considered to have an unacceptable impact on the night time environment.

46. 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 CAA have now defined the coverage and operating requirements for such a system. These are laid out in section 4.28; in summary these are:

Coverage Requirements

- The horizontal coverage of the surveillance system shall extend to at least 4 nautical miles (NM) away from the perimeter of the wind farm/group of wind turbines.

- The CAA recommend that a single sensor surveillance solution to have an 8 NM range or a range sufficient to cover 4 NM away from the perimeter of the wind farm, whichever is greater. Where a sensor network is used, (ie more than one radar or sensor) this may vary to provide coverage for at least 4 NM horizontally from the perimeter of the wind farm. The range should be limited to avoid unnecessary RF (radio frequency) transmissions beyond the range required for the detection of targets prior to entry to the zone within which the obstacle lights must be switched on.

- The vertical coverage should extend up to at least 600m AGL measured above the highest part of the turbine or group of turbines. (note this is AGL and not above turbine tip height)

Probability of Detection Requirements

- The system shall successfully detect targets entering the zone between 4-3 NM away from the perimeter of the wind turbines with 99% Pd (probability of detection) of detecting the target when entering or within this zone.

- Where targets are continuously tracked by the radar-based On-Demand Lighting Activation System, the targets shall be tracked until leaving the 4NM horizontal distance away from the perimeter of the wind farm and the vertical boundary with a 90% Pd.

- The required Pd shall be achieved for a target with a radar cross section of $1m^2$.

- An update rate (data refresh rate) of once every two seconds or higher is required

47. Section 4.31 goes on to list the parameters that must be determined for the system to be considered capable of providing the correct performance standards. The surveillance system used for the on-demand activation of wind turbine lighting shall be able to determine the following parameters:

- Probability of detection
- Horizontal position of the target
- Target height above ground level
- Speed
- The CAA also recommend that where possible, the descent rate for descending flights and heading be also determined as these provide useful early indication of the likelihood of the aircraft penetrating to the 3 NM / 1000 ft volume where lights must be activated.

48. The guidance goes on to provide additional detail regarding the general requirements including the type of airspace and the operations that take place within it, the licensing requirements for the radio transmissions that the radar will emit, the requirement to not interfere with other systems, and back up power supply requirements. It also lays down following requirements:

- Unless the system has been activated at least once within a 24-hour period by aircraft, the system must be activated for self-test at least once within a 24-hour interval to verify the operational status.
- Commissioning tests - the system shall be subject to a commissioning test to verify that the system:
  a. Meets the performance requirements stated above.
  b. Correct activation of lighting as per the signals to activate or deactivate lighting.
  c. Correct timing to activate and illuminate the obstruction lights, timers used for automatic deactivation, time to reach full-intensity of lights etc.
- The ADLS must illuminate the obstruction lights in sufficient time to allow the lights to illuminate prior to an aircraft penetrating 1000 ft (304m) above the tallest point of the wind turbine or group of wind turbines in the vertical coverage volume specified above, and prior to, at least, 3 NM horizontally from the perimeter of the wind farm.
- For systems that are capable of continuously monitoring aircraft while they are within the 3 NM / 1000 ft volume, the obstruction lights should stay on until the aircraft exits this volume.
- In the event that the aircraft detection is completely lost while being continuously monitored within the 3 NM / 1000 ft volume, the ADLS must activate obstruction lights and should be continuously illuminated for 10 minutes. Occasional loss of target detections while being tracked in this volume should not switch off obstruction lights until the aircraft has exited the area of vertical coverage limit and horizontal coverage limits specified (1000ft and 3 NM).

49. There is more detail contained within the Reference, however the information above is provided to demonstrate that achieving all of these requirements will be challenging, particularly with reference to detecting the height of an aircraft without additional information provided by an aircraft transponder, which rather defeats the object of having an active radar system. Radar manufacturers such as Terma, who provide the Terma 5002 ADLS radar system using in both Europe and North America, will need to be able to demonstrate how they will achieve what appear to be more demanding parameters than currently required in other parts of the world. It is also the case that ideally the radar should be located within the windfarm, however, where full radar line of sight of the required surveillance area cannot be provided due to the topography, a radar sensor or sensors may have to be located outside the wind farm with additional challenges of site acquisition, planning permissions, security, power supplies etc.

50. It should therefore be noted, that although a radar activated ADLS system will now be acceptable to the CAA, there are still a number of technical challenges to be overcome and it should not, therefore become the default requirement for aviation lighting mitigation at a wind farm. Clearly where the visual impact of even a reduced lighting scheme as provided in Section 1 of this report is considered to be unacceptable, then a planning condition to install an ADLS might be considered appropriate.

Figure 10 Terma 5002 Radar at a Wind Farm in Germany

51. 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. In response to a 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.' The new ADLS guidance does not change this CAA statement which is still relevant.

52. Emerging surveillance technologies – there are a number of non-radar surveillance systems currently in the research and development stage (R&D) being developed as drone detection systems utilizing novel techniques such as passive RF detection. It is possible that this technology may be utilised in the future but it is not currently proven in the onshore wind farm environment.

53. An 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. Paragraph 4.22 of CAP 764 states:

'In some parts of UK airspace, there are no legal requirements for aircraft to carry and operate radios and/or devices that broadcast an aircraft's location in space and in most cases its altitude (e.g. transponders or ADS-B). Therefore, the use of passive sensors for ADLS in these areas may require additional mitigation. An example might be the use of a Transponder Mandatory Zone (TMZ), although this would be subject to the CAA's Airspace Change Process (further information available in CAA publication 1616)'.

54. The detection parameters of a passive surveillance system would be the same as for the active sensor based system and it is certainly the case that a transponder based system would be capable of providing the required surveillance information for the system to activate in time, unfortunately until there is 100% equipage of aircraft in all airspace, this type of system would not pass an aviation safety assessment without restricting non transponder equipped aircraft from the detection airspace around the wind farm.

55. As mentioned above, the establishment of a TMZ requires following the Airspace Change Process, this can take up to two years to complete and even then, it is up to the CAA to ensure that any proposed airspace change does not lead to any unintended consequences such as the cumulative effect of a number of TMZs, the potential to funnel aircraft into chokepoints or towards high ground or regulated airspace. It is therefore by no means certain that a TMZ would be approved over the windfarm and if a TMZ was refused, any planning condition based on such a solution would not be capable of being discharged. On a slightly more positive note, the CAA have indicated that a TMZ that only required to be activated at night may be able to be established after a shorter consultation period but this has yet to be tested in practice.

56. What is clear is that if or when the carriage of compatible transponders is eventually 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, that are very reliable and relatively inexpensive to install and operate.

Figure 11 ADSB/SSR Passive Aerial

57. Bearing the above in mind, it might be prudent to ensure that lighting installed on the turbines is compatible with any future ADLS system. Alternately, the ADSB/SSR aerials and system could be installed when the wind farm is constructed, ready for activation when required

58. It is also the case that an ADLS system may not be suitable for every location, depending upon the nature of aviation operations at night in the area around the wind farm. If located close to the approach for a major airport for example, the lights might be required to be turning on and off continuously but this is very unlikely to be the case at Shepherds' Rig.

Conclusion

59. This report has assessed the requirements for both visible CAA approved aviation lighting and MOD approved Infrared lighting for the Shepherds' Rig wind farm. The resulting layout is set out in Figures 4 and 6 and makes use of both CAA/ANO Red lights and MOD IR lights. The proposed layouts were sent to the CAA and MOD DIO for approval. The MOD will approve the IR lighting layout as there is no concession required and the CAA considered the proposal and responded, approving the layout: their concession letter is at Appendix C.

60. 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 98% 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.

61. The report then discusses the practicality of additional technical mitigation options as described in the latest version of CAP 764 that, should future technical capabilities or regulatory changes to transponder carriage allow, enable the visible medium intensity turbine lights to be switched off for the vast majority of the time and only switched on, on those occasions when an aircraft activates the system

Authors

Sam Taylor BA(Hons) MSc (Climate Change and Policy) – Sam has 15 years experience in radar and visible light propagation modelling, aviation consultancy and aviation related GIS. He is responsible for aviation and radar research and providing modelling results for wind farms throughout the UK against any of the 250 radars in our database. He has also developed the methodology used in our aviation lighting and impact mitigation reports for sites throughout the UK. Sam has worked on over 2000 wind farm proposals in that time throughout the UK.

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 2000 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.

[redacted]

Cdr John Taylor RN (Ret)
Managing Director
Wind Power Aviation Consultants Ltd
www.wpac.co.uk

[redacted]

Sqn Ldr Mike Hale MBE MSc CFS RAF (Retd)
Aviation Consultant for WPAC Ltd

Appendix A Lighting Results Tables

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	4.79	-2.9	218	22	9.5	1.0	X
4	3.74	-3.1	196	20	14.0	1.4	X
5	3.96	-2.7	245	24	15.6	1.6	X
6	3.27	-3.7	149	15	13.9	1.4	X
7	2.4	-4.3	117	12	20.2	2.0	X
11	2.69	-5.2	91	9	12.6	1.3	

Viewpoint 1 Stroanfreggan Bridge (B729)

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	4.19	-3.6	154	15	8.8	0.9	
4	3.15	-4.0	133	13	13.4	1.3	
5	3.24	-3.6	154	15	14.7	1.5	
6	2.47	-4.7	104	10	17.0	1.7	
7	1.62	-5.8	78	8	29.9	3.0	
11	1.84	-6.9	70	7	20.8	2.1	

Viewpoint 2 Stroanfreggan Craig

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	5.58	-2.6	262	26	8.4	0.8	
4	4.54	-2.7	245	24	11.9	1.2	
5	4.94	-2.2	350	35	14.3	1.4	
6	4.38	-2.5	284	28	14.8	1.5	
7	3.51	-2.5	284	28	23.0	2.3	
11	3.96	-3.0	206	21	13.2	1.3	

Viewpoint 3 Guttery Glen (B729

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux$^{10-6}$) at 10%	Obscured
1	4.29	-4.1	128	13	7.0	0.7	
4	3.28	-4.6	108	11	10.0	1.0	
5	3.26	-4.3	117	12	10.9	1.1	
6	2.43	-5.7	80	8	13.7	1.4	
7	1.63	-7.3	75	8	28.3	2.8	
11	1.56	-9.6	75	8	30.7	3.1	

Viewpoint 4 Smittons Bridge

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

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	4.9	-3.5	158	16	6.6	0.7	
4	3.86	-3.9	140	14	9.4	0.9	
5	3.94	-3.5	158	16	10.2	1.0	
6	3.14	-4.3	117	12	11.8	1.2	
7	2.31	-5.0	94	9	17.6	1.8	
11	2.27	-6.5	72	7	14.1	1.4	

Viewpoint 5 Stroanfreggan Cairn

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	4.18	-3.3	176	18	10.0	1.0	M
4	4.28	-2.8	232	23	12.7	1.3	
5	5.11	-2.0	409	41	15.7	1.6	X
6	5.73	-1.9	448	45	13.7	1.4	
7	5.67	-1.5	642	64	20.0	2.0	
11	7.05	-1.7	535	54	10.8	1.1	

Viewpoint 6 Head of Ken Valley

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	6.69	-1.7	535	54	12.0	1.2	
4	5.66	-1.6	584	58	18.2	1.8	
5	5.69	-1.4	706	71	21.8	2.2	
6	4.83	-1.6	584	58	25.0	2.5	
7	4.05	-1.4	706	71	43.1	4.3	
11	3.61	-2.5	284	28	21.8	2.2	

Viewpoint 7 Southern Upland Way at Culmark Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	8.25	-1.1	949	95	13.9	1.4	
4	7.26	-1.0	1055	106	20.0	2.0	
5	7.77	-0.8	1314	131	21.8	2.2	
6	7.27	-0.8	1314	131	24.9	2.5	
7	6.41	-0.6	1580	158	38.4	3.8	
11	6.81	-1.0	1055	106	22.7	2.3	M

Viewpoint 8 Minor Road south of B729

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	5.82	-3.1	196	20	5.8	0.6	X
4	4.98	-3.3	176	18	7.1	0.7	
5	4.61	-2.9	218	22	10.3	1.0	X
6	3.66	-4.1	128	13	9.6	1.0	
7	3.24	-4.0	133	13	12.7	1.3	
11	2.04	-7.9	75	8	18.0	1.8	

Viewpoint 9 High Bridge of Ken

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	5.91	0.9	2117	212	60.5	6.1	
4	5.63	1.3	1895	190	59.9	6.0	
5	6.51	1.3	1895	190	44.7	4.5	
6	6.86	1.2	1955	195	41.5	4.2	
7	6.51	1.6	1643	164	38.8	3.9	
11	7.82	0.9	2092	209	34.2	3.4	

Viewpoint 10 Southern Upland Way, Benbrack (Striding Arch)

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	6.7	-2.5	284	28	6.3	0.6	
4	5.86	-2.4	304	30	8.9	0.9	
5	5.48	-2.4	304	30	10.1	1.0	
6	4.53	-2.9	218	22	10.6	1.1	
7	4.12	-2.7	245	24	14.4	1.4	
11	2.91	-4.8	100	10	11.7	1.2	

Viewpoint 11 B7000 at East Arndarroch

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	6.35	-1.9	448	45	11.1	1.1	X
4	5.62	-2.1	409	41	13.0	1.3	X
5	5.11	-1.6	584	58	22.4	2.2	X
6	4.19	-1.8	488	49	27.8	2.8	X
7	3.97	-2.8	245	24	15.5	1.6	
11	2.62	-5.4	87	9	12.7	1.3	

Viewpoint 12 Dundeugh Hill

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	2	6.2	88	9	21.9	2.2	
4	3	4.9	145	14	16.1	1.6	
5	2.73	5.8	98	10	13.2	1.3	M
6	3.61	4.4	186	19	14.3	1.4	M
7	4.37	4.1	221	22	11.6	1.2	M
11	5.11	2.9	500	50	19.1	1.9	M

Viewpoint 13 Beninner

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	3.4	6.2	88	9	7.6	0.8	X
4	4.39	4.9	145	14	7.5	0.8	X
5	4.04	5.7	103	10	6.3	0.6	X
6	4.86	4.3	197	20	8.3	0.8	
7	5.66	4.0	236	24	7.3	0.7	
11	6.26	3.1	429	43	10.9	1.1	

Viewpoint 14 Cairnsmore of Carsphairn

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	5.41	-0.7	1451	145	49.6	5.0	X
4	5.75	-0.8	1314	131	39.7	4.0	
5	4.9	-0.7	1451	145	60.6	6.1	
6	4.96	-0.7	1451	145	59.0	5.9	
7	5.74	-0.2	1934	193	58.7	5.9	
11	5.3	-0.9	1314	131	46.7	4.7	

Viewpoint 15 Craig of Knockgray

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	5.44	1.6	1643	164	55.5	5.6	M
4	6.13	1.8	1390	139	37.0	3.7	M
5	6.67	1.8	1390	139	31.2	3.1	M
6	7.56	1.6	1643	164	28.8	2.9	M
7	7.86	1.8	1390	139	22.5	2.3	M
11	9.13	1.2	1955	195	23.4	2.3	

Viewpoint 16 Alhang

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	13.97	-1.4	706	71	3.6	0.4	
4	13.14	-1.3	776	78	4.5	0.5	
5	12.74	-1.2	858	86	5.3	0.5	
6	11.8	-1.3	776	78	5.6	0.6	
7	11.4	-1.2	858	86	6.6	0.7	
11	10.18	-1.6	584	58	5.6	0.6	

Viewpoint 17 Southern Upland Way at Waterside Hill

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	9.35	-1.9	448	45	5.1	0.5	X
4	8.61	-2.2	350	35	4.7	0.5	
5	8.11	-1.7	584	58	8.9	0.9	X
6	7.19	-1.9	488	49	9.4	0.9	X
7	6.92	-2.2	350	35	7.3	0.7	
11	5.6	-3.3	176	18	5.6	0.6	

Viewpoint 18 A713 at Stroangassel

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	5.89	-2.9	218	22	6.3	0.6	
4	5.82	-2.5	284	28	8.4	0.8	
5	4.95	-2.7	245	24	10.0	1.0	
6	4.57	-2.9	218	22	10.4	1.0	
7	5.11	-2.2	350	35	13.4	1.3	
11	4.18	-3.5	158	16	9.1	0.9	

Viewpoint 19 A713 south of Carsphairn

Turbine	Distance (KM)	Elevation Angle	Candela	Candela at 10%	Microlumens per square metre (lux10-6)	Microlumens per square metre (lux^{10-6}) at 10%	Obscured
1	9.58	0.1	2064	206	22.5	2.3	X
4	9.95	-0.8	1314	131	13.3	1.3	X
5	9.09	-0.9	1181	118	14.3	1.4	M
6	9.08	-0.9	1181	118	14.3	1.4	
7	9.8	-0.6	1580	158	16.5	1.6	
11	9.12	-1.0	1055	106	12.7	1.3	

Viewpoint 20 Woodhead Mines

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	14.62	1.1	2006	201	9.4	0.9	
4	14.56	1.3	1895	190	8.9	0.9	
5	13.7	1.5	1743	174	9.3	0.9	
6	13.24	1.5	1743	174	9.9	1.0	
7	13.65	1.6	1643	164	8.8	0.9	
11	12.44	1.5	1743	174	11.3	1.1	

Viewpoint 21 Corserine (Hennessey's Shelter)

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	6.08	-3.0	206	21	5.6	0.6	
4	6.22	-2.5	284	28	7.3	0.7	
5	5.33	-2.7	245	24	8.6	0.9	
6	5.16	-2.8	232	23	8.7	0.9	
7	5.83	-2.1	378	38	11.1	1.1	
11	5.1	-3.1	196	20	7.5	0.8	

Viewpoint 22 Carsphairn War Memorial

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..Infrared
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

Communications, Strategy and Policy Group
Windfarm Policy

UK Civil Aviation Authority

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

25 May 2026
Ref Windfarms / Shepherds Rig Wind Farm

Dear Mike,

Proposed Obstacle Lighting Scheme for Shepherd's Rig Wind Farm

Reference: Shepherd's Rig Wind Farm aviation obstacle lighting proposal AL3 dated 5 March 2026

1. Thank you for the lighting proposal at reference. The document discusses the proposed obstacle lighting plan for the Shepherd's Rig Wind Farm, located 10 km north of St John's Town of Dalry and 2 km to the east of the Glenkens (A713) valley.

2. The proposed Shepherd's Rig Wind Farm consists of 11 turbines, with heights 220m ground to tip. This brings the turbines 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 proposed lighting scheme has some mitigation proposed with 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, T04, T05, T06, T07 and T11;
- 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 (note that both lights should not be lit at the same time);

25 May 2026 Page **1** of **2**

- 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 5 km;
- infra-red lights to MoD specification installed on the nacelles of turbines T01, T02, T03, T04, T05, T06, T07, T08, T09, T10 and T11 (note that dimming permission is applicable only to visible lights, not infra-red lighting).

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

7. This letter supersedes the CAA lighting scheme variation letter dated 11 February 2025.

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

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

Yours sincerely,

[redacted]

Andy Wells
Manager Aviation and Wind Turbine Policy

Appendix D CEL-WT-MIC Specification

CEL AVIATION LIGHTING

DATASHEET

05 Dec 2024

Medium Intensity Red 2,000cd Light

230VAC - LED Aircraft Warning Light

CEL-WT-MIC - StandAlone / Modbus

Medium Intensity stand-alone 2,000cd red model is designed for Wind Turbine Installations. This intelligent light offers unique features such as incorporated fault monitoring, photocell, GPS synchronisation, adjustable luminosity and supports both stand-alone and Modbus operation as a part of a larger CEL aviation light system network.

Key features

- 2,000cd (effective) RED fixed or flashing modes
- Extremely reliable - long lifetime
- Supports both stand-alone and Modbus operations
- Suitable for Ofsh ore environment
- Incorporated GPS synchronisation
- Adjustable luminous output levels 10%, 30%, and 100%
- Incorporated photocell and fault monitoring
- WIFI interface
- Design lifetime more than 20 years
- 5yr warranty- the longest in the industry

Specifications met

- ICAO International Standards and Recommended Practices: Aerodromes Annex 14 Volume 1, 8th Edition, July 2018,
- Chapter 6: Medium-intensity Type B/C Fixed Obstacle Light
- European Aviation Safety Agency - Chapter Q — Visual Aids for Denoting Obstacles CS-ADR-DSN.Q.848
- FAA Advisory Circular 150/534543F 09/12/06: L-864 and L-885
- CEL-WT-MIC - light measurement chart table - DEC2024

Optical characteristics

- 2,000cd (effective)
- Colour aviation RED
- NVG compliant infrared (850nm)
- Horizontal beam 360°
- Vertical beam 3°
- Maximum intensity at -1° is less than 1,110cd
- Maximum intensity at -10° is less than 56cd

Electrical characteristics

- Operating voltage 90-265VAC
- Constant power input at 95% by active PFC
- Flash rates: 20/30/40/60fpm
- Meets standards
  EMC (Emissions): EN 61000-6-4
  EMC (Immunity): EN 61000-6-2

Electrical characteristics - continued

- Power consumption
  17W @Night (RED, 40fpm)
  20W @Night (RED+IR, 40fpm)
  25W @Night (RED, fixed)
  30W @Night (RED+IR, fixed)
- Recommended cables (Outdoor):
  Power (L-N-PE): 3x1,5mm" or 3x2,5mm"
  Data: CAT 7
  Alarm: CAT 7, 3x1,5mm or 3x2,5mm"
  Power + Data: 6x1,5mm" or 6x2,5mm"
- Input/Output terminals can be used to daisy chain power and data to additional lightheads

Mechanical characteristics

Painted marine grade aluminium body (C5MHigh)
Glass cover
Degree of protection IP66
Operating temperature range -40...+55°C
Mounting 240x240mm
Height 333mm, diameter 270mm
Weight 11kg

Additional Factory-Installed Options

Cold-climate version (CCV)
NVG compliant infrared (IR)

OPERATING VOLTAGE 230 VAC
CAUTION I LED RADIATION

Contarnex Europe Limited
252 Martin Way
Morden, Surrey SM4 4AW
United Kingdom
T: +44 (0)20 8395 6006
E: info@contarnex.com
www.contarnex.com
www.aircraftwarninglights.co.uk

EASA
Wifi

Page 1 of 2

Technical information in this document is subject to change without notice. Copyright© CEL2024 Dec 2024

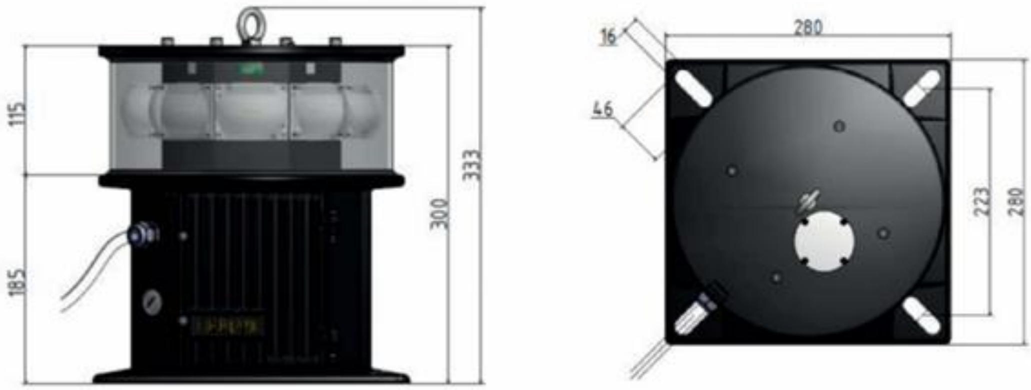
www.contarnex.com

Medium Intensity Red 2,000cd Light

230VAC - LED Aircraft Warning Light

CEL-WT-MIC - StandAlone / Modbus

CEL-WT-MIC
Light unit with mounting dimensions



CEL-WT Versions

CEL-WT-MIB	Medium-intensity Type B (flashing) obstruction light, 2,000cd Red, GPS sync, Photocell, Alarm, 100-240VAC Supports stand-alone and Modbus Network operation.
CEL-WT-MIC	Medium-intensity Type C (steady burn) obstruction light, 2,000cd Red, infrared, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.
CEL-WT-MIB-IR	Medium-intensity Type B (flashing) obstruction light, 2,000cd Red, Infrared 850nm, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.
CEL-WT-MIC-IR	Medium-intensity Type C (steady burn) obstruction light, 2,000cd Red, Infrared 850nm, GPS sync, Photocell, Alarm, 100-240VAC. Supports stand-alone and Modbus Network operation.

Contarnex Europe Limited. 252 Martin Way, Morden, Surrey SM4 4AW, UK
T: +44 (0)20 8395 6006 E: info@contarnex.com - W: contarnex.com - W: aircraftwarninglights.co.uk